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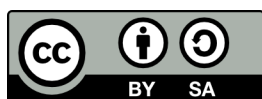
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Engaging Science

innovative teaching for responsible citizenship

Online Course Content

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Funded by



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FOREWORD

Kathy Kikis-Papadakis

This book “*ENGAGING SCIENCE: Innovative teaching for responsible citizenship*” provides a detailed overview of key pedagogical tools for Science Educators in Europe. This open licensed content translated in various languages and localised to address various national curricula has been implemented through MOOC in various countries in Europe. The ENGAGE “CPD on/for RRI” framework *demonstrates its relevance to RRI teaching/learning content and structure* by helping secondary science teachers address contemporary science issues, develop beliefs and knowledge for RRI and enrich their practices through teaching strategies based on inquiry pedagogies.

For various countries, providing teachers with a detailed book, which explains RRI teaching strategies and practical activities in the classroom, is of great importance by encouraging them to attend and complete the online course. This document was explicitly asked for by teachers during our face-to-face national workshop (evaluation feedback in Greece). The ENGAGE team considers that providing this book to teachers before the course will facilitate participants to focus on online activities: reflection, discussion and teaching practices during the course deployment. Consequently, online collaboration with other teachers and expert facilitators will enrich their learning and teaching practices.

This course content is a comprehensive guide based on a well-conceptualised and three phases-inclusive “ADOPT, ADAPT & TRANSFORM”, which are the basis of ENGAGE CPD framework. This content provides useful information on the course content and structure, and the requirements for attendance and for successful completion. This work has the potential to make a broader contribution to the field of CPD on/for RRI, as a guide/exemplar for supporting teachers’ practices to deal effectively with controversial socio-scientific issues in the classroom. To this respect, the document acts as a sustainability vehicle for RRI projects.

Engage Consortium includes 14 Institutions from 12 countries with extensive experience in Inquiry based Science Education and Responsible Research and Innovation, particularly in teacher training and curriculum design.

Partners also have wide networks, which will be used to multiply the stakeholder involvement and impact.

Online Teacher's community will be built around:

- Science-in-the-news and Open curriculum materials
- Open Online Courses for just-in-time learning
- Partnerships system for school-scientist projects

In order to maximise student achievement, ENGAGE builds on a range of:

- research-informed pedagogies
- guided inquiry
- explicit skills teaching

ENGAGE professional learning and curriculum development approach is based on three-stage path:

- Adopt phase: combines exciting learning materials, online community and online courses and workshops for coaching and feedback.
- Adapt phase: offers expert's toolkit of examples, explanations, anecdotes and activities to help students learn effectively.
- Transform phase: provides open-ended Projects put teachers and students into partnership with practising scientists, to learn about RRI directly.

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This course will help you:

1. Address contemporary science issues and applications relevant to students.
2. Develop beliefs, knowledge and classroom practice for responsible citizenship.
3. Provide students a strong foundation to engage in science issues they will meet during their lives.

During our course we encourage you to share your strategies and comments on the materials website related to your lesson.



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Rating summary

Now that scientists have discovered that sugar is like an addictive drug, pressure is building for action to reduce the amount of sugar that children and young people consume in sugary drinks. In this activity, students consider the evidence for causal links between sugar consumption, obesity and disease. They then weigh up arguments for and against banning sugary drink sales to under-18s.





Equipping the Next Generation for Active Engagement in Science



Ban Cola?

For more, visit [EngagingScience.eu](#)

1 of 15


Science objective

Digestion: Describe possible health effects of unbalanced diets from data provided. Critique claims for a diet by analysing nutritional information (*KS3 Science Syllabus*)


Enquiry objective


Draw conclusions: Know how to judge whether the conclusion is supported by the data (*KS3 Science Syllabus*)


Designed for the



Try the activity


[Ban Cola Presentation](#)
Size: 3.52 MB


[Ban Cola Teachers Guide](#)
Size: 595.00 KB


[Ban Cola Student Sheets](#)
Size: 1.53 MB

Curriculum link

England National Curriculum KS3:

- Working Scientifically: Analysis and evaluation – interpret observations and data, including identifying patterns and using observations to draw conclusions.
- Biology: Nutrition and Digestion – the consequences of imbalances in the diet, including obesity.

GCSE Combined Science subject content:

- Working Scientifically: Analysis and evaluation – interpreting observations and other data, including identifying patterns and trends, making inferences and drawing conclusions.
- Biology: Health, disease and the development of medicine – diseases influenced by nutrition.

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rmackay says:
 January 24, 2016 at 9:43 pm ([Edit](#))

Useful discussion task

Students were thoroughly engaged even though they looked at all the evidence critically, many thought the taste was just too good to surrender.

SCIENCE FOR RESPONSIBLE CITIZENSHIP

Alexandra Okada

Science Education plays an important role for responsible citizenship in the contemporary age ^{[1][2]}. Progress and development in Technology and Science are the basis for a better future. However, innovations must address societal needs in accordance with societal values in order to maximize the benefits and reduce any harmful impact. Therefore, citizens must be equipped at an early age to understand socio-scientific issues, applying science knowledge, ethical values and inquiry skills to form evidence-based opinions.

The 21st century is marked by the pace of scientific advancement. Latest discoveries related to various emergent fields such as nanotechnology, artificial intelligence, biotechnology are frequently announced to citizens through science-in-the-news. These daily innovations often highlight issues closely connected to people's lives, for instance, food security, enhanced health, energy and environment. On the other hand, the impact of scientific innovation is unpredictable and requires scientific knowledge and skills for reflecting on social and ethical implications. This requires societies being able to deal with promises and uncertainties, particularly to develop a better understanding of its potential benefits and risks ^{[3][4]}.

The European Commission has highlighted the importance of **Responsible Research and Innovation (RRI)** in Science Education through its Science in Society programmes (FP7 and Horizon 2020). Experts on RRI suggest key questions for inclusive engagement with responsible citizenship: *“Why do it? For what purpose and goals? Are these desirable? What are the motivations? Who could benefit and how? Who might not benefit?”* ^[5].

Various European projects have been helping teachers foster students' inquiry-based learning (IBL) skills to enable them to discuss socio-scientific issues ^[6]. Some recent initiatives have also highlighted the importance of innovative teaching to empower students to make decisions based on informed opinions, evidence and relevant scientific content ^[7], such as the ENGAGE project ^[8].

The ENGAGE project aims to spread the teaching and learning of RRI at scale, by connecting cutting-edge Science and Technology with educative



RI – “Responsible Research and Innovation” is a new concept highlighted by the European Commission that refers to the transparent and interactive process by which citizens and innovators helping each other by sharing their informed-based opinions and ethical views about innovative products or innovation methods, particularly about their potential risks and benefits.

materials. Our goal is to reach 12.000 teachers and 300.000 students in 14 countries. For that, the ENGAGE platform (EngagingScience.eu) combines Open Educational Resources (OER) for students, Open Online Courses (MOOC) and Community of Practice (CoP) for teachers. It targets three components: students' interest, science knowledge and inquiry skills.

Responsible Research and Innovation (RRI)

RRI is an inclusive approach to ensure that societal actors can understand risks and benefits of scientific developments and make a responsible decision. The RRI curriculum developed by ENGAGE (Fig. 1) presents a framework which integrates science-in-society knowledge and inquiry skills. It is based on European curricula and the US Next Generation Curriculum Science Standards (NGSS). Science-in-society knowledge refers to four key areas: Technology impact, Big Science, Values thinking and Science-Media. ENGAGE project aims to increase awareness of RRI with young students by providing free access materials for students developed based on RRI curriculum. Science-in-society Knowledge refers to four key areas: Technology impact, Big Science, Values thinking and Science-Media.



Figure 1 – RRI curriculum: four key areas and eight inquiry skills

RRI considers that technology and science progress are the basis for a better future. However, innovations must be planned carefully to address societal needs in accordance with societal values in order to maximize the benefits and reduce any harmful impact. The ENGAGE RRI curriculum, therefore, aims to equip students to be able to form evidence-based opinions on societal needs and social values. The ENGAGE materials and pedagogical tools then were designed to help teachers support students in understanding four emerging areas and develop eight inquiry skills.

The four emerging areas provide relevant background for ENGAGE materials and learning activities:

- 1. Technology Impact:** Technological and Scientific developments are the basis for a better future but must be planned carefully in order to maximise the benefits and reduce risks, particularly any harmful impact.
- 2. Big Science:** Science is no longer an individual search for knowledge, but a collaborative and complex enterprise, done in teams. Funded largely by corporations and governments and politically determined, it favours practical applications and key areas in society. This means responsible innovations must address societal needs in accordance with societal values such as people, environment and economy.
- 3. Values thinking:** In emerging science and technology, there are often uncertain issues with unclear implications that require socio-ethical thinking. Decisions should be made by taking into account the views and concerns of various perspectives and actors in societies.
- 4. Science-Media:** Much of our scientific information is interpreted by the media, who may give an unbalanced, biased, black and white or sensationalised account. The source of information needs to be assessed in terms of its purpose, scientific credentials and currency. Critically read media reports about science, identify data, evidence and values thinking used to back up the claims, as well as evaluate its strength in terms of repeatability and reproducibility.

The Responsible Research and Innovation (RRI) dimension to the dilemma will help students understand that the purpose of research in science is multi-faceted, constantly developing and driven by the needs of society. In an ever evolving world, these needs are changing and RRI has to be open and transparent allowing all researchers, technologists and citizens to interact with it.

Scientific inquiry skills for RRI focus on ten abilities with the aim to equip students for active engagement in contemporary science. Teachers in the ENGAGE community have been including various comments on the project website to highlight their student's achievements. As illustration, we selected an example for each skill:

- 1. Devise Questions:** Define a clear scientific question which investigates cause or correlation relationships between different factors.

"The car wars project that has started a few weeks ago really inspired students to create more questions in science. It engaged them and motivated them to learn." (Car wars) 19/06/2015.

- 2. Interrogate Sources:** being able to question different sources and assess their validity and trustworthiness by judging the reliability of the source, check for bias and evaluate evidence for claim.

"Students commented that they could have been reading different stories! At this point, I (teacher) explained that they were the same "issue" but in different newspapers." (Giant Virus) 27/06/2014.

- 3. Examine consequences:** being able to evaluate the merit of a solution or competing solutions to a real-world problem, based on scientific ideas, principles and empirical evidence, by identifying and reflecting on consequences and/or logical arguments regarding relevant economic, societal, and environmental considerations.

"Students were stimulated to look at all the issues surrounding the dangers of this virus and vaccination pros and cons". (Ebola) 31/10/2014.

- 4. Estimate risks:** being able to measure risks and benefits by assessing its probability, weighing up and combining its probability and the scale of its impact as well as balancing against the benefits to the individuals or groups affected.

“A lot of pupils knew the benefits but not the risks of scientific issues, e.g. they were able to explain what a tanning bed is, but none the danger linked to it”. (Ban-the-Beds) 14/09/2014.

- 5. Analyse patterns:** being able to interpret observations and data in a variety of forms to identify patterns and trends by making inferences and drawing conclusions.

“Students used real data suggested in the materials to bring questions, analyse and interpret”. (Solar roadways) 17/12/2014.

- 6. Draw conclusions:** Deciding whether the claim made by a piece of research is supported by sufficient data.

“Students were able to integrate science knowledge and inquiry procedure, for instance, to elaborate the menu for the canteen by describing sourcing the insects with detailed information.” (Eat Insects) 17/07/2015.

- 7. Critique claims:** being able to check strength (quality accuracy and sufficiency) of evidence provided and identify lack of clarity of justification, by commenting on whether the reasoning follows logically from the evidence and provides strong support to the claim.

“Students questioned other groups’ beliefs and the level of concerns.” (Giant Virus) 27/06/2014.

- 8. Justify opinions:** being able to synthesise scientific knowledge, implications, and value perspectives into an informed opinion by describing key arguments supported by empirical evidence and scientific reasoning and identifying values based thinking, to support or refute a viewpoint on an issue or a solution to a problem.

“Secondary pupils developed three urban inquiries on: Energy Consumption (Appliance Science), Electric Cars (car Wars) and Solar panels (Solar Roadways). They used ENGAGE and two platforms weSPOT and nQuire-it for creating their investigations and interacting with researchers, science educators, non-academic experts and parents. First, learners



Access our website for materials, online course and community of practice: Engaging Science.eu

created scientific questions and collected data in weSPOT. Second, they discussed data to facilitate their analysis in nQuire-it. Third, arguments were co-constructed to support their evidence-based reports in Litemap tool. Three posters were co-authored showing their conclusions and presented at the ICTPI 2015 International Conference on Technology Policy and Innovation.” (MOOC UK01) 09/07/2015.

- 9. Use ethics:** Being able to understand and use three kinds of ethical thinking: utilitarianism, rights and duties, virtues in order to make informed decisions and explain why different people may have different viewpoints about an issue.

“The series of lessons offered an extra dimension for the students to hook their knowledge and understanding scientific issues, for example, genetic inheritance onto, the issues/dilemmas of taking a test, the ignorance of some and possible prejudice of others.” (Take test) 21/04/2014.

- 10. Communicate ideas:** Being able to effectively describe opinions and accomplishments with text and illustrations, both orally and in writing, in a range of formats, using the major features of scientific writing and speaking.

“Students practiced various inquiry skills, particularly elaborating argument, arguing and communicating science.” (MOOC UK01) 17/07/2015.

The ENGAGE team helps teachers develop new strategies collaboratively to equip students for active engagement in science. A big challenge is to change how science is taught in European schools ^[9]. This means moving from teaching focused primarily on science as a body of content to equipping students with the knowledge, skills and values to use science in society ^[10].

In order to tackle this issue, we invite you to discuss challenges and opportunities as well as co-creating knowledge for innovating teaching’s practice.

Join our community, welcome to **ENGAGE!**

ENGAGING SCIENCE . EU

The European project ENGAGE is part of the “**Science with and for Society**” initiative for promoting Responsible Research and Innovation’ (RRI). ENGAGE provides teachers with curriculum materials to get students to talk and think about socio-scientific issues that impact in their life and the planet as a whole. It also offers online courses for teachers to enrich their practices through easy-to-use tools based on scientific inquiry pedagogies. The content focuses on four pedagogical tools that are useful on the three stages of CPD framework: adopt, adapt and transform.



Science with and for Society” –

is one of the key programmes of the European Commission to address societal challenges. It aims to help teachers develop innovative ways of connecting science to society, make science more attractive to young people and increase society’s interest and skills for innovation.

The ENGAGE CPD framework is based on three phases, which indicate the degree to which science and society content is integrated with traditional science content for learning:

- **Stage 1 Adopt:** minor change – extending topics already taught with dilemma lessons. It presents little RRI content for motivational purposes to be applied in short lessons.
- **Stage 2 Adapt:** significant changes – teaching inquiry processes with problem-solving lessons. There is a casual infusion of more RRI content but with no explicit purpose.
- **Stage 3 Transform:** major changes – teaching science content with a Scenario-based topic. There is a purposeful infusion giving even more time to RRI.

This online course aims to discuss four ENGAGE tools:

- Chapter 1: Dilemma
- Chapter 2: Group Discussion
- Chapter 3: Problem-Solving
- Chapter 4: Conversation

What you will learn and/or share in our ENGAGE community of practice:

- Using productive dilemmas to engage students to think and talk about socio-scientific issues.
- Setting up effective group discussions for students to share and apply their science knowledge to make decisions.
- Preparing students for effective conversations by building arguments based on evidence.
- Planning and designing problem-based lessons with argumentative conversation for RRI/inquiry skills.



Sign in engaging-science.eu in order to participate in the ENGAGE community and access the materials or the online course.

You will experience collaborative planning, reflective implementation and supportive review of an engaging science lesson.

Materials and the Online course are available in the ENGAGE project website.

Teachers invest a lot of time using curriculum resources in their classrooms. Bruner in the 1960's ^[11] suggested their 'educative' power for embedding new approaches. Eijkelhof et al. ^[12] argue that educational materials are "both effective and efficient" in the way they can communicate a rationale for new content and pedagogy, and help teachers deal with implementation problems.

Curriculum materials are one of the key strategies of ENGAGE and often overlooked as a component of CPD.

Materials in our 'teacher inquiry cycle' facilitate the first process of 'classroom experimentation'. They are published as 'Open Educational Resources' (OER) on our Knowledge Hub (website), to encourage their free use, modification, and re-publishing by teachers, under a Creative Commons license. Any third party shall be allowed to utilise this published foreground for free for non-commercial educational purposes.


The choice of materials as a key strategy is based on other criteria:

- **Attracting very large numbers of teachers.** Research acknowledges the relative lack of suitable teaching materials to make RRI-teaching feasible and attractive (Eijkelhof & Kapteijn, 2000). Ours are based on the recent 'Science up8'

project developed by the Sheffield Hallam University with the Association for Science Education. The Upd8 materials brought the science behind the news into teachers' classrooms while highlights were still fresh. Almost every school in the UK, as well as 50,000 teachers worldwide, downloaded them over 2 million times, used its materials. The ENGAGE materials are based on the same principles, but now focus on topical socio-scientific issues in Europe that are attractive for teachers to engage students and prepare them with skills for everyday life in European countries.

- **Easy to use exemplification with positive student outcomes.** The ENGAGE team consider that if your first attempts at classroom experimentation produce positive student outcomes, this will more lead to you continuing to use the strategy until it becomes practised. Thus, Materials work as the springboard for the process of reflection - 'why did it work'? 'Which is the next stage in the inquiry learning cycle'.
- **Replicable quality across partner countries.** The ENGAGE team carried out a detailed curriculum analysis which identified very strong overlaps in the knowledge and skills underlying 'the nature of science' and 'inquiry' in all curricular frameworks at 11-16^[9]. We developed a common set of curriculum resources, which were translated and localised. Doing so means we concentrated our resources on achieving a very high quality. This was vital to achieve our quality criteria of student engagement, ease of teacher use, and successful embedding of RRI knowledge.

To make ENGAGE materials relevant to each country, there '**localisation**' stage assures that the learning objectives of student's materials can be adapted to the national framework, and particular aspects of pedagogy can be emphasized locally.

 **ocalisation'** – is a phase in materials production where specific details and cultural references can be changed

**OSE' –**

Website: <http://roseproject.no/>
The Relevance of Science Education (ROSE) project investigated views and perceptions of the students as learners about Science and Technology. Their aim was to inform discussions about how enhance students' interest in science and technology in ways that respect cultural diversity and gender equity, promote personal and social relevance and empower the learner for democratic participation and citizenship.

In Europe, we know what emergent areas of Science and Technology students are likely to be interested in from **ROSE** research, and this varies little across countries, but is quite different for boys and girls (see Gender). However, sometimes the issues are more global and less personal such as energy and climate. For these, we use techniques taken from professional science communication, such as creating human stories and highlighting 'extremes and limits'. We consult initially our key stakeholders in each country - teachers and students. We then search OER websites for source material related to socio-scientific issues, such as UNESCO (<http://en.unesco.org>)

ENGAGE is producing three different kinds of materials: I.Topicals, II.Sequences and III.Projects. Each Material is published with three components:

- Presentation slides – backbone of lesson, PowerPoint.
- Student Sheets – PowerPoint.
- Teachers Guide, with curriculum links and a lesson plan with commentary.

We aim to cover areas common to all partners' 11-16 science curricula identified in the detailed analysis which takes place in the first, foundation phase of the project. Over the two years of the programme, we rolled out a collection of 20 Topicals (every few weeks, 10 per year). In the process we 'covered' all the main emerging technologies linked to the common areas of fourteen countries' curricula in Europe. This is encouraging the regular usage and word-of-mouth dissemination needed to achieve our ambitious targets. Teachers are visiting the ENGAGE website regularly when they know that they will usually find a Material which covers the area they are teaching.

The materials provide a broad, balanced of key areas of emerging technology in all scientific disciplines which are likely to affect students in their lifetimes, from nanotechnology and novel materials to genomic medicine and genetic modification, to human enhancement, to geo-engineering. We ensure the coverage and the delivery of the 'RRI curriculum' by pre-compiling the list of topics, and the issues within them so that we are ready to react quickly to news stories relating to the topic.

In our model, materials include pedagogical strategies for RRI-teaching (see Concept), for instance, small group discussion. These are embedded within the Materials, with clear instructions and all the presentation material and student sheets to help teachers take 'easy steps'. There is also a short formative

assessment built in, to check student learning (i.e. to show positive outcomes, and facilitates further experimentation). ‘Teachers’ notes’ following the style of science upd8 have a detailed commentary on managing the strategy and ‘signs of success’ teachers should look for.

Topicals

The aim of TOPICAL materials is to get you onto the path of RRI science. Topical contexts are the main and unique element to make ENGAGE materials highly engaging for your students. RRI issues, from applications of genetics, to human enhancement, regularly appear in the news. Such relevant contexts also have a proven impact on achievement according to Schroeder (2016). So TOPICAL Materials focus on getting your students to practice skills and knowledge already taught. This allows them to be short (from 20 minutes), and easy to fit into existing topics. The format of a Dilemma lesson is:

Lesson:

Dilemma: get students’ attention set up a Dilemma question in students’ minds.

Engage: review the essential science content, through a short activity.

Extend: an involving activity for students to develop their views or a resolution of the Dilemma.

Evaluate: teacher-led reflection on the learning.

Sequences

SEQUENCE material refers to a series of two lessons with more advanced activities also presented with PowerPoint slides to teach inquiry processes. Its aim is to help your students explore ways to solve problems and explain solutions through argumentative conversations. It includes a provocative problem emerging from a real life issue. The requirements for the problem-solving are similar to the six criteria for a ‘scientific dilemma’, but it includes also “Need to know”. It covers the whole inquiry process and science concepts for students to solve the problem. Your students will gain insight into not only the skills but also the science concepts and principle involved in carrying out the processes (e.g. data analysis). The format of a SEQUENCE lesson is:

<p>Lesson 1 - science</p> <p>Engage: focus students on learning after getting their interest.</p> <p>Review: help them recall key concepts to apply in a new context.</p> <p>Consider: help them identify evidence about the issue in discussion.</p>	<p>Lesson 2 - skills</p> <p>Re-engage: remind them of the key points, e.g. question and concepts.</p> <p>Play: decision-making process inquiry following steps of a game.</p> <p>Decide: justifying decision based on knowledge skills and values.</p>
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Projects

It refers to a group of lessons to teach science content and inquiry skills ending in a performance assessment. Your students will investigate more independently by practicing inquiry skills, applying science concepts and developing awareness of responsible actions. The strategies for implementing an Engaging Science project will be published in the next volume of the ENGAGE collection.



CHAPTER 1 **dilemma**

The aims of Dilemma lesson are help teachers:

1. Get students engaged to think and talk on socio-scientific issues.
2. Examine the six criteria for a productive dilemma lesson.
3. Understand the RRI principles: four areas and eight skills used to design the ENGAGE materials.

Summary

- Dilemma is a controversial socio-scientific issue related to applications and implications of Science considered a productive learning context for help learners develop science understanding, skills and attitudes for decision-making or problem-solving.
- Materials in the ENGAGE project are designed to stimulate your students thinking in science and are based on dilemma and inquiry-based learning.
- **Teacher's role:** check if the lesson is appropriated based on students' scientific knowledge and conceptual understanding, capture student's motivation and attention with the context, foster student's evidence-based opinion through discussion where everyone can participate in and assess their contributions and achievements in the lesson.
- **Teachers' strategies:**
 - **ENGAGE:** make the context more dramatic, encourage students to make questions and compare their reactions;
 - **EXTEND:** listen to students' discussion groups and check their understanding, support them in interpreting sources of evidence and justifying their response to the dilemma
 - **EVALUATE:** use self- or peer- assessment and get their feedback about their learning (difficulties, achievements and procedures).

1.1 Introduction

We are frequently faced with challenging decisions or **dilemma** to make in our everyday life, some which have big and some small implications on outcomes.

Science also faces these decisions and scientific discoveries and consequent technological applications can determine the course of future human endeavour and activity. From the classic of Robert Oppenheimer's development of the atomic bomb over 70 years ago which lead him to become rapidly aware of the consequences of his work and to subsequently advocate world control of nuclear power to the current scientific questions such as vaccination, obesity, carbon capture; consequences of decisions can have profound effects on the way we live now and in the future and all members of society need to be aware and informed of these issues. This drives the democratic argument for science education.



lemma – is a situation in which a difficult choice has to be made between two or more alternatives, especially equally undesirable ones (Oxford dictionaries, 2015).

Dilemma in Science Education refers to controversial socio-scientific issues related to applications and implications of Science ^[13]. Dilemma in the content of ENGAGE project includes a productive learning context to facilitate learners' construction of science understanding, skills and attitudes as well as strengthen decision-making and problem-solving skills ^[14].

Engaging pupils in dilemmas will not only give them access to knowledge, but also skills to use this knowledge in an informed way, to stimulate their interest in science, to teach them the importance of evidence in decision making and, importantly, to help them appreciate and value the ideas and opinions of others ^{[15][16]}.



Reflect on your Portfolio (Wiki)

Which event in the last 50 years do you consider to be a significant scientific dilemma?

1.2 Dilemma lesson

A socio-scientific issue involves scientific knowledge and social and moral implications ^{[17] [18]}. For example, CERN is searching for a new family of particles to explain dark matter but the scientific instrument needed – the Large Hadron Collider (LHC) has a budget of over 7 billion Euros and uses 10% of Geneva’s energy consumption, is this a justified use of funding and energy sources?

Materials in the Engage project are designed to stimulate your students thinking in science and are based on dilemma, discussion and evaluation for inquiry-based learning. The scientific knowledge or concepts are presented in a context which will challenge their thinking and personal opinions and encourage them to draw on scientific knowledge and evidence to make decisions and construct new understanding.

Not all socio-scientific issues are accessible to students and it would be inconceivable to imagine that they could solve all the world’s problems such as the one above (though of course they will have an opinion).

By engaging learners in debate and discussion around issues (see Fig. 2) which may have a direct effect on their lives, such as “should we ban sugary drinks”, they will learn to examine the evidence of the claims and assess wider aspects of issues. They will take into account, for example, the effects of sugar substitutes, the impact is on the subsistence farmers who grow the sugar beet, the related health cost of obesity in their discussions and arguments.

ENGAGE DILEMMAS



Figure 2 – Slides Dilemma: **SlideShare**



SLIDESHARE
<http://www.slideshare.net/alexandraokada/uk2015a-engage-dilemma>



Activity

Explore the Engage materials at engagingscience.eu.

Download one of the topical material and look at the suggested context, scientific knowledge and teaching approaches.



Forum: Topical Material

Post a short comment about the material that you selected: say which lesson you downloaded and how you think your students would respond to the lesson. Observe if other participants are interested in the same lesson for group discussion and lesson planning.

1.3 Dilemma for inquiry-based learning

ENGAGE uses an active approach to teaching inquiry skills. Students will be at the centre of their learning, but this requires a very structured and organised approach prepared and facilitated by the teacher because it presents some pedagogic challenges.

In order to plan Inquiry Lessons using ENGAGE materials, teachers will need to:

1. Ensure that the scientific knowledge is at an appropriate level and that students understand the concepts involved.
2. Create an environment where students' opinions are valued but where decisions are reached using the evidence base presented.
3. Structure discussions so that all students are heard.
4. Assess the students' contribution to the activity and their achievement in the task.

ENGAGE dilemma approach is based on a short cycle with 3 stages, adapted from the 5 E's inquiry cycle ⁽¹⁹⁾⁽²⁰⁾

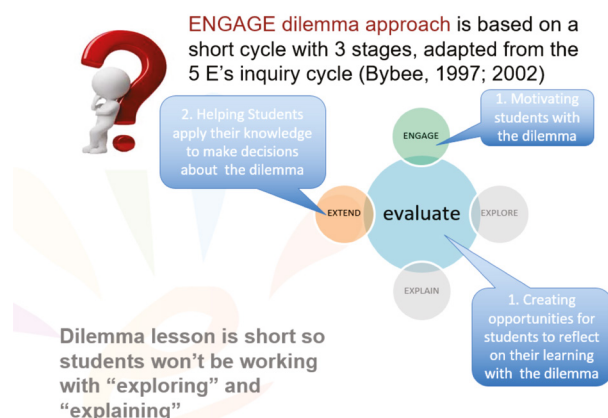


Figure 3 – Engage - Extend - Evaluate from the 5E's inquiry cycle

These are skilled teaching tasks and the ENGAGE courses are designed to help you develop your skills in a phased approach.

In the first phase, the teaching sequences will take place after your normal teaching of the concepts. They can be used as enrichment activities which will reinforce and provide an opportunity for you to assess student's performance.

Our examples are thoroughly prepared and tested and based on the sound and evidenced approaches of three steps of 5E's of inquiry cycle of learning Engage, Extend and Evaluate. A constructivist philosophy underpins this learning cycle, one where students are encouraged to express their own understanding and build on this understanding with new evidence, experience, presented through learning activities.

1.4 Teachers' roles

Teachers must help students in the three phases of Inquiry-based lesson: ENGAGE

- Capture their attention with the context.
- Activate previous or informal knowledge.
- Be curious and use the "dilemma" as their "own learning objectives".

EXTEND

- Use their relevant knowledge to solve the problem.
- Apply their inquiry (RRI) skills to find a solution.
- Justify an overall decision or evaluation.

EVALUATE

- Get feedback to improve their performance.
- Reflect on what they learned from the lesson and how.

The dilemma will **engage** student thinking, use knowledge and evidence to make a decision about the dilemma; **extend** their understanding and **evaluate** their learning. This is not to say that the “explore” and “explain” elements of the cycle are not important, but as the materials will be used following the previous teaching, these elements will have already been addressed. Therefore, the emphasis will be on Engage, Extend and Evaluate.

1.5 Teachers’ strategies

Teachers can use various strategies during each stage of dilemma lesson:

ENGAGE

- Find out about the new story to become enthusiastic yourself.
- Make the context more dramatic using props or demonstrations.
- Ask questions to relate the Dilemma to students’ experience.
- Get students to compare their reactions to the question.

EXTEND

- Listen in to group discussions.
- Ask questions to check understanding.
- Remove scaffolding in student sheet for more advanced students.
- Support students in interpreting sources of evidence.
- Support students in justifying their response to the dilemma.

EVALUATE

- Use formative assessment techniques to assess students’ understanding.
- Get students to self- or peer- assess the outputs.
- Ask students what was easy or difficult in the task, and how they solved the problem.

You will adapt your teaching style and approach to incorporate the Engage, Extend and Evaluate elements of inquiry (Fig. 4). These elements perform beginning, middle and end to the dilemma activity or an alternative analysis to the approach could be input, process and outcome. Each element

is equally important and can be delivered in different ways. For example, the stimulus could be to show a short video clip, access a news story or use an artefact to generate enthusiasm for the topic. We refer to this as the ‘hook’ to the learning.

It is important that teacher does not lead and give answers but facilitates or activates the learning. A dilemma is not solved by the teacher, it is owned by the students. This is particularly important in the Extend phase of the inquiry. You will ask questions, scaffold and prompt students in the activity and have a vital role to play. The outcome of the learning should be assessed but again try giving the responsibility to the learners; assessment does not necessarily have to be based on formalised or traditional mechanistic tasks.

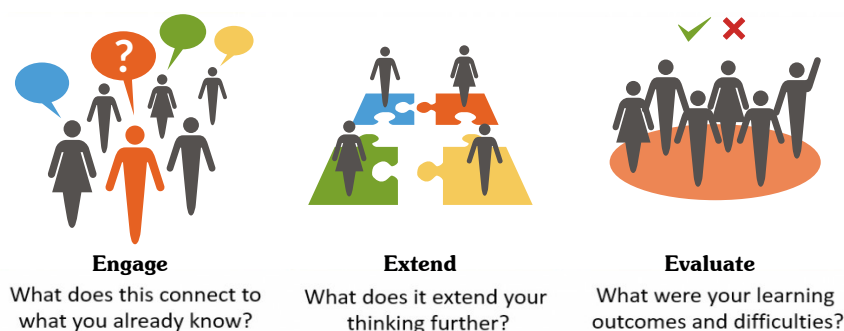


Figure 4 – Engage, extend and evaluate: key questions



Activity

For a short explanation of the 5 E's go to:

<http://www.nasa.gov/audience/foreducators/nasaclips/5e-teachingmodels/> or for more detail go to: http://sites.nationalacademies.org/cs/groups/dbassesite/documents/webpage/dbasse_073327.pdf.



Forum: Topical Material (Individual)

1. What are your opinions of the Inquiry cycle: ENGAGE - EXTEND - EVALUATE? Have you used this in your teaching? Have you adapted the cycle at all for your use? How do your students respond to this approach?
2. Using your downloaded lesson as an example, how would you hook the students into the activity?
3. What different ways could you assess the outcome of the learning?
4. What do you see as the biggest challenge for you address in this approach to inquiry?

1.6 Criteria for an engaging dilemma

Not all real-life issues are equally effective for teaching curriculum science. The six ‘Dilemma’ criteria (Table 1) have been carefully chosen through experience and evidence from other similar curriculum developments, for example, Upd8 in the UK (ud8.org.uk). The criteria encompass the pedagogical, scientific, social and moral aspects which underpin Engage. The stimulus for the activity is a crucial to the success of the activity. It provides the ‘hook’ to the curriculum and has to be a dilemma which is relevant to the student’s experience if they are to engage with activity in a constructivist and productive way.

Criteria	The Dilemma should be ...
1. ENGAGING	Interesting to most students. It has a 'hook'. Hooks are stories with strong human interest: popular topics with boys/ girls, concerns about the future, lifestyle, disasters, celebrities.
2. AUTHENTIC	a real question, choice, or action that students might consider in response to news in the media about emerging science or technology.
3. CONTROVERSIAL	Should not be an obvious choice or action for students, in order to merit thought and discussion.
4. COVERED	an issue that requires the use of science in its resolution, which applies knowledge that is part of the national curriculum (or equivalent), at an appropriate age-level.
5. SOCIAL	a decision-making scenario, based on scientific knowledge influences the life on the individual including the impact on society, environment, economy etc.
6. RRI	a problem that requires an inquiry process (RRI) e.g. technology, big science, values thinking, scientific media, define problems, evaluate solutions, construct arguments, critique arguments , interrogate media, communicate ideas.

Table 1: Six criteria of productive dilemma

Controversy is important to ensure that students engage both with their feelings and their knowledge. There should be no obvious answer to the dilemma, and ideally the issue should have currency to attract student’s attention. Research suggest that creating cognitive conflict can accelerate learning where there are real choices to be made by students (CASE, 2010). It has to be a given criteria that the dilemma has to involve science with a link to the curriculum at an appropriate level. Attainment in the prescribed curriculum framework is why the dilemma is used, how it is used by the

teacher will determine the level of success. The socio-scientific nature of the dilemma allows students to place their scientific understanding in a context which has meaning and impact on their lives, enabling them to meet the dual goals of learning science and being better-informed citizens who are able to apply scientific knowledge when faced with moral democratic choices.

The example shows how the ENGAGE dilemma lesson 'Ebola' meets the criteria. Note how the disaster hook leads students into a more detailed understanding of the spread of disease and the risks and benefits of developing a new vaccine. Teachers can create their own Dilemma lessons, by using the same 6 criteria to select a suitable Dilemma.

- 1. Engaging:** Ebola can spread quickly with devastating consequences. It is timeless, presents "hooks" and disaster.
- 2. Authentic:** Scientists are developing drugs and vaccines to help fight it.
- 3. Controversial:** Learners are asked if they would trial the Ebola vaccine.
- 4. Covered:** Working Scientifically: Scientific attitudes: Evaluate risk. Biology: Inheritance, chromosomes, DNA and genes: a simple model of chromosomes, genes and DNA in heredity.
- 5. Social:** Weigh up risks and benefits and make a decision. Use scientific knowledge of the function of genes.
- 6. RRI:** Develop scientific thinking: evaluate personal, social, economic and health implications. Make decisions based on the evaluation of evidence and arguments; - Evaluate risks both in practical science and the wider societal context.

Engaging pupils in dilemmas will not only give them access to knowledge, but also skills to use this knowledge in an informed way, to stimulate their interest in science, to teach them the importance of evidence in decision making and, importantly, to help them appreciate and value the ideas and opinions of others.



Forum: Topical Material

Take another look at the lesson you previously selected and comment on how the criteria map on to this lesson.

Task 1 Dilemmas in Science Teaching

Let's discuss: what is a good or bad dilemma?

1. What are the criteria that you identified in your lesson of a good dilemma?
2. How do you think your students would respond to this lesson?



CHAPTER 2 group Discussion

The aims of group discussion lesson are help teachers:

1. Learn how to set tasks, form groups, prepare groups and support discussion.
2. Reflect on challenges experienced and considering solutions.
3. Understand the challenges of setting up and evaluating discussions linked to issues with moral and ethical concerns.

SUMMARY

- Group Discussion aims to provide opportunities for interactions between teacher and students as well as students and peers. It creates opportunities for everyone expressing ideas, questions, curiosity and reflection (no right no wrong)
- There are five key steps to apply group discussion effectively:
 1. decide the structure of the discussion,
 2. set the tasks by checking student's knowledge, short tasks, output, conflict for engagement),
 3. form small groups, by including friends, specific roles and organised environment,
 4. prepare discussion with clear ground rules and scripts to develop productive discussion, and
 5. support participation: listen in, then support or challenge, deal with issues, move between small and whole group.
- Students' role: leader, listener, reporter, encourager, reflector.
- There are six group discussions' formats:
 1. **Conscience alleyway** is a quick role-playing, which helps students deal with big science issues.
 2. **Consequences wheel** is a visual mapping type activity, all participants can develop their own ideas.
 3. **Mind movies** are about students thinking creatively to solve problems and make decisions collaboratively.
 4. **Two Stray, One Stay** refers to students moving around the room while working with peers to solve problems.
 5. **Jigsaw** is a reading technique, which helps students specialise in one aspect of a topic.
 6. **Four Corners** is a technique that stimulates student practice skills through movement and discussion: listening, communication, critical thinking, and decision-making.

2.1 Introduction

An important element of using socio-scientific issues in science teaching is enabling students to discuss the issues and express their opinions and idea. In this section, we will look at techniques for structuring and supporting effective group discussion.

Group discussions are an important approach in school science teaching, particularly when the context of the lesson is based on a socio-scientific issue.

Well-structured discussions enable students to be faced with challenges and decisions to make about the topic (cognitive conflict) and to crucially understand the difference between opinion and evidence-based conclusions.

Students learn from and value each other's views, gaining confidence and competence.

This section will help you prepare a group discussion and select appropriate teaching strategies. It will encourage you to reflect on the strategies and approached and to understand how effective discussions contribute to students' learning.

2.2 Group-discussion lesson

Engage lessons use group discussion as an essential part of the approach. They encourage:

- **Small group work:** ENGAGE Materials aim put students in groups of 3-4 to work on a collective task, without direct supervision by the teacher.
- **Collaboration:** The tasks are designed to be collaborative i.e. they ask students to work together and collectively as a group come to a decision or solve a problem.
- **Authenticity:** The tasks are based on authentic issues that have a connection to real problems and questions, i.e. ill-structured problems with multiple solutions rather than right or wrong.

- **Ethical consideration:** Some of the problems can be approached not only by using of scientific knowledge, but also by basing decisions on ethical or moral concerns.

Group Discussion involving socio-scientific issues, ethical aspects and decision-making is an interplay of meanings and ideas mainly from students and affords a different type of questioning..

Discussion aims to provide opportunities for interactions between teacher and students as well as students and peers:

- **Expressing ideas, no right or wrong:** More specifically, students need opportunities to express their own ideas (even if they are not always correct or well-structured), listen to their peers ideas, evaluate and critique ideas, and revise and integrate them as well. Classroom talk should centre on engagement and thoughtfulness.
- **Asking teachers and peers:** Students should ask questions that arise from their own interests or confusion—and they should ask questions to each other as well as to the teacher.
- **Triggering curiosity and provoking deep reflection:** Teachers should pose questions that push students to think more deeply about what they have observed, experienced, or read.

2.3 Key benefits

ENGAGE materials aim amongst other to put students in groups of 3-4 to work on a collective task, without direct supervision by the teacher. The tasks are designed to be collaborative, for example, students work together and collectively as a group to come to a decision or solve a problem. Tasks are also based on authentic issues based on ill-structured problems with multiple solutions rather than right/wrong. Some of these problems can be approached not only by making using of scientific knowledge, but also by basing decisions on ethical or moral concerns. There are some advantages of working with others.

There are six reasons we believe that it is important for teachers to use student-student interaction for teaching socio-scientific issues or RRI:

1. It practises how students will engage with controversial issues beyond school, through opinion sharing, discussion and negotiation.
2. It can be easier to get students to learn actively when they have more control and choice.
3. There is time for all students to contribute to discussion, so everyone can try out and share new ideas in an environment.
4. Students can learn from each other (to gain confidence and competence), using another's ideas to help build their own, evaluating ideas, and comparing solutions.
5. Shy or less articulate students may find it less threatening than speaking out in class, and easier to talk without the barrier of teacher-approved language.
6. Students enjoy it!



Reflect on your Portfolio (Wiki)

What are the key issues to use group discussion effectively?

2.4 Teachers' strategies

It is important to prepare the discussion as part of the lesson plan. Simply saying 'let's discuss' to students is unlikely to provide an effective learning experience. A group lesson can be developed through five steps (Fig. 5).

Organising the Discussion



Figure 5 – Group discussion lesson - SlideShare

1. Decide

Initially, you need to think about the overall structure of the discussion; start with the objectives and intended outcomes of the lesson and choose a suitable teaching approach to achieve the objectives.

Reflecting on challenges and solutions: Since most teachers have already used group discussions and have probably found it challenging, it is good to build on their experience - and start with a diagnostic or ‘trouble-shooting’ approach. Once teachers have identified the challenges they have experienced and its most likely cause, they will be more likely make use of the solutions.

Samples are shown in the table:

If your challenge is	The cause might be ...	See ‘best practice in
Students go off task after a while	Lack of structure or accountability for an output was	Setting Tasks
Low level of discussion	No differences of opinion to stimulate proper argument	Forming Groups
A few students ‘sabotage’ the group	Lack of clear ground rules about acceptable behaviour	Preparing Groups
Students are not listening to each other	They need to develop listening skills	Preparing Groups
Students stop talking when you drop in	Students expect teacher to supply answers	Supporting Groups

Table 2: Group discussion challenges



Reflect on your Portfolio (Wiki)

Look at your downloaded Engage materials and explore how the discussion is used in the activity.

2. Set tasks

Check students have sufficient knowledge: Discussion is more productive if students are confident with the expected prior knowledge that they will need to use in their discussion. In ENGAGE materials, there is a starter to recap science concepts before their implications are discussed. Our tasks also make it clear what are facts (not to be questioned) and what are evidence/opinion (can be argued about).

ENGAGE example: the Ebola activity

In the dilemma students faced was 'will you test a new vaccine?'.
Before they could come to a decision they needed to understand how the vaccine works.

They used their knowledge of genes to discuss and explain this.

Keep tasks short and structured: Less experienced students are likely to wander off topic, and it is best to start with short focused tasks. To encourage high-level discussion, ENGAGE tasks have a 'discussion agenda', listing the points to be discussed, to ensure students know what to talk about, and know when they are on/off topic. On the other hand, over-structuring the task can stop students from thinking for themselves.

ENGAGE example: the Invasion! activity

In the dilemma students faced was 'should we introduce ragweed-eating insects?'.
Focused task: Students were given information and asked to answer one important question.

Group discussion: They then presented their answer to the rest of the group.

Make groups accountable for an output: The best way to ensure students learn without supervision is to define a clear output for the task e.g. to solve a problem or come to a group decision. This should be reported back in some form so that students know they have responsibility to achieve the output.

ENGAGE example:

In the BanCola activity groups are asked to feedback their opinions to the rest of the class.

These are then used to initiate a whole class discussion.

Create conflict: Students will be more likely to engage in arguing if they see a reason to do so - conflict. ENGAGE tasks create conflict by having sources which disagree, or by putting students into roles which have differences of opinion. Research indicates that conflict and the need to build on each others' views improves the quality of discussion and reevaluation of students' positions.

ENGAGE example: the 3 Parents activity

In students are introduced to a controversial procedure and are asked 'should the new it be allowed?'.

Groups study arguments from different viewpoints with differences of opinion.

These help students come to an informed decision.

3. Form Groups

Use groups of 3 to 4 students: Sometimes students discuss in pairs, but this can lead to students seeing it as a situation of right/wrong whereas with 4 students they will more likely see a range of opinions to be evaluated. Although a group can be up to 6, smaller groups help to avoid having students sitting on the sidelines while others dominate.

Try friendship groups: Group dynamics play a big part in a discussion. Students won't discuss until they feel confident with their peers, and that it is OK to argue/conflict opinions. So stick with the same groups for a while. Friendship groups (which are generally single-sex) are worth trying, as they have been found to function more effectively than groupings that the teacher has decided.

Give students discussion roles: Allocating roles can lead to more effective discussion when the roles support group interaction (and avoid students working independently). Leadership is vital to keep the discussion focussed and to uphold the ground rules.

- Leader: reads the assignment, restates points, mediates conflict, and manages time.
- Listener - asks probing questions, or asks for better explanations, or recalls areas left out.
- Reporter - get group to answer his questions in order to report back.
- Encourager: gives team members feedback, is responsible for ensuring that all group members are heard.
- Reflector: who keeps track of group process and makes comments about focus, listening skills, participation.

Organise the environment: Some laboratories present obstacles for small group discussion. Ideally students should sit in small circles, close together. Everyone needs to be facing each other if they are to talk to one another.

4. Prepare discussion

Students need to know the behaviour expected of them when taking part in a group. Too often these are left without being explored. Ground rules for discussion can be identified as a class. An effective way to get students to follow them is to get them to write the list for themselves and to display it within the group. Then encourage students to refer to these whenever an issue arises. Try to keep this as a set of positive rather than negative statements (do's rather than don'ts).

Establish the ground rules upfront

Students need **to know the behaviour expected when taking part in a group:**

- Ground rules for discussion can be identified as a class.
- An effective way is to get students to write the list for themselves.
- They can discuss a list of rules for common agreement.
- Then encourage students to refer to these whenever an issue arises.

The most fundamental rule is listening to others.

The whole purpose of discussion is **to see things from perspectives different from our own:**

- everyone's opinion is listened to and respected.
- everyone takes responsibility for good behaviour.
- Silence is O.K. Think before speaking.
- Don't interrupt or ridicule others.
- If you don't understand, ask for clarification.

Use practice exercises to develop discussion skills: Try short exercises to build specific skills, before students start the discussion. For instance, there are many games to promote better listening e.g:

- **Being heard:** Pair up participants. One person talks about a hobby while the other person is instructed to ignore them. Discuss the frustration that can come with not feeling heard, and review strategies a good listener should practice.
- **Listening accurately:** One student reads a short story, and the others have to paraphrase. This activity shows how we prioritize certain information over others.



Reflect on your Portfolio (Wiki)

Summarise what you think the three most important factors are in establishing an effective discussion.

Listening actively: One talks about a location they'd like to visit, but gives only hints as to the specific place. The listener has to pick up on these subtleties and at the end, recommend a suitable place. The original speaker will confirm or deny whether this and the two discuss ways people can pick up on the appropriate cues to play a more vital role in discussions.

Provide scaffolds and scripts to develop discussion skills: One approach is to focus task on particular skills, and provide students with scaffolds to structure their initial practice attempts, or scripted language prompts to guide them. Here is a 3 part scaffold for structuring a contribution (it is an ADAPT Tool which goes into the full claim/explanation/reasoning framework):

1. *Link:* I'd like to comment on [Name's] point about.... Or I'd like to make a new point
2. *Express:* I think/believe , Or my opinion is that ...
3. *Support:* My reasons are ... I think/believe that because ...

Here is a set of scripted language prompts for the skill of 'disagreeing with others':

Say This	Instead of This
I don't think I agree. Could you explain?	That doesn't make sense at all.
I disagree because ... ' I see it differently because ...	Wow! Is that ever dumb.

I think we should check our notes and the original assignment.	That is not what the teacher asked us to do.
It might be better to ... Have you considered ...	You are dead wrong.
Does everyone agree?	Let's vote on it.
I understand how you feel, but I think you might consider also...	That really offends me!

5. Support discussion

Teacher's role during the discussion is to act as a facilitator. This is a challenging role, you need to remain impartial from the discussion but to be aware of what is taking place in each group. You will need to be attentive and sensitive to different roles taken by the student and intervene only when necessary. It is very easy to be drawn into a discussion, but you need only to prompt and support where and when necessary. Timing is very important, set clear timescales and stick to them, students need to know how long they have to discuss and achieve the output. You will need prompts for this task.

Listen in, then support or challenge

Drop in on groups for short periods. As they may stop talking when a teacher appears, make sure they know you're just there to listen. When they continue talking in your presence, decide whether your input will be a) give them more support in the mechanics of discussion, or b) challenge them to discuss on a higher level.

Deal with emerging problems

Noise can be a problem, and needs to be kept to a productive level. Don't allow one group to become too noisy or they will attract interest from other groups, who will lose their identity. Some student' behaviours may fall into one of these categories which will require action. Here are some suggestions:

- Silent/shy students: invite them directly, ban interruptions, and congratulate small contributions.
- Clowns/distractors: confront and explain problem, give guidance and reward better behaviour, separate from anyone who encourages this behaviour.
- Apathetic/bored: Place with friends, give them a specific role, and encourage contribution.
- Dominant/over-talkative: explain problem (but praise contribution) allocate a recording or leadership role, place with similar students.
- Duellists/aggressors: identify reasons, suggest preferred

behaviour and advise on self-control and resolving conflict, separate known duellists.

Move between small group and whole group

Show students their discussions are valued by getting contributions from individual groups and sharing these with the whole group. Draw out similarities and differences, and get individual students to give reasons for the range of views.

Anticipate sensitive issues

- If there are students who are vulnerable to the discussion topic, either warn them in advance, make sure they are in an understanding group, or let them sit out.
- The discussion is more productive if students are confident with the expected prior knowledge that they will need to use in their discussion. In the ENGAGE dilemma lesson, the concepts will have been covered previously but the materials include suggestions for starter activities to recap the science concepts before their implications are discussed.
- Less experienced students are likely to wander off topic, and it is best to start with short focused tasks. But take care, over-structuring the task can stop students from thinking for themselves.
- It's important that there is an outcome or output to the discussion. This should be reported back in some form, so that students know they have responsibility to achieve the output.
- Students will be more likely to engage in argumentation if they see a reason to do so. Research indicates that conflict and the need to build on each other's views improves the quality of discussion and re-evaluation of students' positions.
- It is important to prepare the discussion as part of the lesson plan. Simply saying 'let's discuss' to students is unlikely to provide an effective learning experience.



Forum task 2

What do you see as the main benefits and challenges to using discussion in the classroom?

What do you see as the outcomes of group discussion? What are the issues that you might face or faced in the supporting discussions?

2.5 Methods for group-discussion

Six Group Discussion Methods

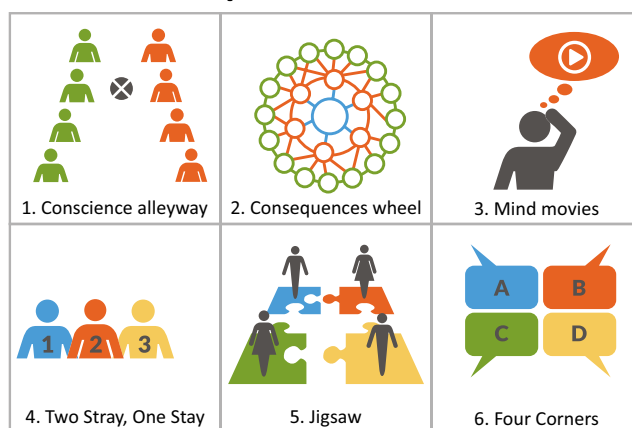
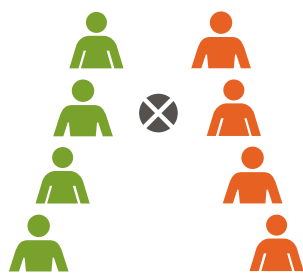


Figure 6 – Group discussion methods - SlideShare



These different approaches can be used to set discussions (Fig. 17). Various examples were illustrated in ENGAGE slides presentation in the first page of this unit. In summary:

1. **Conscience alleyway** is a quick role-playing, which helps students deal with big science issues.
2. **Consequences wheel** is a visual mapping type activity that encourages students to think of the primary and secondary consequences of a particular action through visual mapping. All participants have a chance to develop their own ideas.
3. **Mind movies** are about students thinking creatively to help them solve problems and make decisions.
4. **Two Stray, One Stay** refers to students moving around the room while working with classmates to solve problems and answer questions. As students talk about their ideas and thinking process with others, it helps them develop a deeper understanding. All participants have chance to engage in group discussion and collaboration with open-ended or controversial questions.
5. **Jigsaw** is a reading technique, which helps students specialise in one aspect of a topic. It helps students learn about different viewpoints on a certain topic, event or discovery.
6. **Four Corners** is a technique that stimulates student learning through movement and discussion. It helps learners specialise in one aspect of a topic and develop skills: listening, communication, critical thinking, and decision-making.



I. Conscience alleyway - quick role playing to help students deal with big science issues.

How to use?

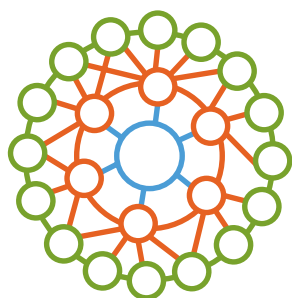
1. Explain the dilemma Ask students to think about how they feel about it.
2. Split them up into 3 groups: A, B and C.
3. Get the students from A and B to form two lines facing each other with an alleyway through the middle.
4. Ask students from group C to pass through the Conscience Alleyway whilst the students from A and B whisper their ideas.
5. Group C students express their newly informed feelings to the rest of the group.
6. After reflecting upon what group, A and B students said to them.
7. It can be repeated if time allows, then each group can pass through the alleyway.

When to use? Good for exploring new topics to get a quick overview of where the participants are in their own understanding of things.

ENGAGE example: At the start of the GM decision activity, students are asked whether they will buy GM cereal. The Conscience Alleyway could be used to gather thoughts, feelings and opinions on GM food.

II. Consequences wheel - a visual mapping type activity.

How to use?



1. On paper, the students write the main topic: action or event related to the dilemma in a centre circle.
2. Students write direct consequences of the main action each within a circle and connected by a line radiating outwards from the centre to form a first layer of consequences.
3. Students then consider second order consequences around each of the direct primary consequences. These secondary consequences are linked to the primary consequences by drawing double lines.
4. The students can continue with third order consequences and so on.
5. Students can highlight positive or negative consequences (e.g. + pros / - cons or different colours).

6. Students can compare and contrast their consequences through group discussion.
7. This may lead on in turn to exploring new issues.

When to Use? As a way of generating discussion around a topic.

ENGAGE example: In the Grow your own body activity, students are asked to give their friend advice on whether to choose a lab grown organ or a human transplant.

After studying the information they can use a consequence wheel to map out the actions of each choice to help them come to a decision.

III. Mind movies - students think creatively

How to Use?

1. **The students close their eyes.** The teacher reads out the dilemma to the class.
2. **Students are asked to imagine** what is happening with a dilemma in their mind.
3. Once the scenario has been explained, the students are asked to continue where the teacher left off to **complete the story in their mind.**
4. Then students are asked to **share their stories in groups** of between 2-4.



When to Use? This creative tool can be useful when introducing a new topic. It is a good way of generating discussion amongst students.

ENGAGE example: At the start of Big Bag Ban the students can visualise the problems caused by plastic waste. They can then discuss possible solutions.

IV. Two Stray, One Stay - Students move around the room while working with classmates to:

How to Use?

1. **Group** (Arrange students into groups of three)
Assign each student a number (1, 2, or 3) and a letter to groups (A, B, C, D...).
2. **Assign** (Give all groups the same assignment)



Explain a dilemma task to perform, a problem to solve, or a question to discuss.

Tell that each member will be going to another group to share ideas, they need to be able to tell their response.

3.Move (Swapping students after groups formulating their response).

All students number 1 stand up and rotate to the next group ($A \Rightarrow B$, $B \Rightarrow C$, $C \Rightarrow D$, $D \Rightarrow A$) Then, all students number 2 stand up and rotate two groups ($A \Rightarrow C$, $B \Rightarrow D$, $C \Rightarrow A$, $D \Rightarrow B$).

Student #3 stays in his or her original position.

4.Interview (Students interview one another about their results and way to solve it in new groups).

Everyone should take notes and prepare to take the new ideas back to their own original group.

5.Return and Share (After five to ten minutes, all students return and share outcomes to their original groups) As the original group of three, they will each share what they learned from the other groups they worked with.

When to Use? After reading a text to compare and contrast conclusions to a science topic.

ENGAGE example: This could be used to help students complete the main task in the activity Solar roadways.

V).Jigsaw - Reading technique

How to Use?



1. Prepare (Prepare four separate reading selections on the content). Put students into groups of four. These groups will be the “home groups” of the jigsaw. Prepare a direction sheet to help students answer questions and gather information.

2. Introduce to Home Groups (Divide the class into their home groups) Explain the strategy and the topic of study. Tell students that they are going to be responsible for teaching one segment or selection to the group they are sitting with now.

3.Break into Expert Groups (students move to sit with a group assigned to the same selection). First, ask students to begin reading to themselves, or have them take turns reading aloud. Second, the group should discuss their selection/topic, fill out their direction sheet. Third, they decide what and how they should present to their home groups.

4. Regroup with “Home Groups” (they return to their home groups to create & share a summary).

Each student is responsible for teaching their selection/topic to their home group.

All students are responsible for learning all material.

Determine how you’d like students to organize and summarise all the information (graphic organiser or a poster).

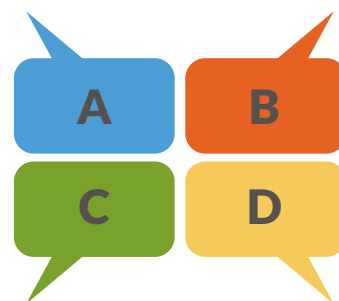
When to Use? Focusing on complementary – or divergent – concepts

ENGAGE example: This technique could be used in the main activity of Life on Enceladus. Expert groups could look at each evidence card and make a conclusion before feeding back to home groups.

VI). Four Corners - Reading technique through movement and discussion.

How to Use?

- 1. Prepare** (Generate a controversial statement or a question related to your topic of study) Create four different opinions (e.g 1. “Strongly Agree,” 2. “Agree,” 3. “Disagree,” and 4. “Strongly Disagree”) or four possible answer choices to related to the dilemma and post these chart papers in four areas. Each corner of the room is labeled as A, B, C, or D.
- 2. Present:** (Read the statement or problem to the class, without giving them choices) Allow time for students to independently think about an answer to the statement/question. They can write down their answer and reason for their choice. Then, provide the answer choices and ask students to choose the option that are similar.
- 3. Commit to a Corner** (Ask students to gather in the corner of the room that corresponds to their choice) In each corner, students form subgroups of 2-3 to discuss the reasons for selecting a particular choice.
- 4. Discuss** (Call on students to present a group summary of their opinions).
Allow two or three minutes of discussion before. They can share an oral presentation or a written statement.



When to Use? Before introducing new material to tap into prior knowledge. After watching a debatable film clip to gauge a reaction or reading a short text to begin a discussion. **ENGAGE example** This technique was used in the activity Making decisions. A simulation is used to show the consequences of making a decision. Students show their decision before the simulation by going to a corner. After the simulation, they can 'move or stay' to the corner of their new choice.

Teachers' role during the discussion is to act as a facilitator.

This is a challenging role, you need to remain impartial from the discussion but to be aware of what is taking place in each group. You will need to be attentive and sensitive to different roles taken by the student and intervene only when necessary. It is very easy to be drawn into a discussion, but you need only to prompt and support where and when necessary.

Timing is very important, set clear timescales and stick to them, students need to know how long they have to discuss and achieve the output. You will need prompts for this task.

Task2: Applying dilemma with discussion in your lesson

Post your guidelines for discussion here (easiest to copy and paste into the message).

Assignment1: Report on your practice

1. Write down the ENGAGE material that you selected.
2. Describe the group preparation, method(s) used and your role.
3. Include challenges and outcomes.

Please, insert 5 sentences about Engage lessons.



CHAPTER 3 Problem Solving

The aims of problem-solving tool are to:

1. Understand how to structure a two-lesson sequence that explicitly teaches an inquiry process, and applies science understanding.
2. Explore how 'Thinking Guides' can help students learn inquiry processes.

Summary

- Problem-solution lesson refers to provocative problem emerging from a real life issue, by which students will gain insight into not only the skills, but also the science concepts and inquiry principles involved in carrying out the processes.
- The key issue is divided into two questions, one per lesson: Lesson 1: What is the scientific evidence behind the issue?; Lesson 2: How do you make an informed decision?
- The sequence material follows a two lesson structure: Lesson 1 science (Engage - Review science - consider evidence) and Lesson 2 skills (Re-engage - Play - Decide).
- ENGAGE teaches about 10 different RRI skills involved in solving problems, making decisions and communicating them:
 1. Interrogate sources
 2. Use ethics
 3. Estimate risks
 4. Examine consequences
 5. Justify opinions
 6. Devise question
 7. Critique claims
 8. Analyse patterns
 9. Communicate ideas
 10. Draw Conclusions
- Some strategies: 1. engage students, 2. create a 'need to know' the process, 3. help them consider evidence, 4. apply the lesson game to practice using RRI skill, 5. use thinking guides to support reflection, evaluation and feedback and finally 6. support students to decide and communicate their evidence-based conclusion.

3.1 Introduction

The concept of “problem-solving” is grounded on problem-based learning, which is a student-centered approach.

Students learn about a scientific issue through the experience of solving an open-ended problem. They practice both inquiry skills and domain knowledge.

In ENGAGE, a problem-solution lesson refers to provocative problem emerging from a real life issue.

The requirements for the problem are similar to the six criteria for a ‘scientific dilemma’, but it includes also “**Need to know**”. It covers the whole inquiry **process** and science concepts for students to solve the problem.

Students will gain insight into not only the skills, but also the **science concepts and inquiry principles** involved in carrying out the processes (e.g. data analysis).

This Section shows:

- The importance of reviewing relevant scientific content needed to address issue.
- How to split science content + process (because of working memory).
- Teaching cognitive strategies for inquiry processes.

3.2 Problem-solving lesson

Lesson sequence model

The key issue is divided into two questions, one per lesson:

- Lesson 1: What is the scientific evidence behind the issue?
- Lesson 2: How do you make an informed decision?

Example: In animal testing the issue is “should we ban animal testing for drug development”. The two questions that structure the lessons are:

Lesson 1: Is animal testing essential for drug development?

Lesson 2: How can ethical thinking help you decide about the ban?

Key concepts

The key concepts of the problem-solving lesson are scientific evidence and inquiry skills (e.g. ethical thinking).

The lesson 1 question focuses on a specific context, asthma drugs, which gives the opportunity for students to apply their understanding of breathing, to this new context.

Lesson 2 teaches three ethical thinking strategies: utilitarianism, rights and duties, and virtue ethics.

There are three ethical thinking strategies ^[21] suggested by some ENGAGE materials:

- 1. Utilitarianism:** an action is morally right if the consequences of that action are more favourable than unfavourable to everyone.
- 2. Rights and duties:** equally rigid systems of moral rules.
- 3. Virtue ethics:** less emphasis on learning rules, and instead stresses the importance of developing good habits of character, such as benevolence.

The European project Getting Evidence into Practice (GEP) builds on a broad definition of ‘evidence’. Evidence is not restricted to the results of “hard” scientific research, but should be seen as the broader answer to the question regarding what works ^[24]. This definition also allows the use of other valuable information sources, including the views of experts and examples of good practice. In this way, evidence can encompass data derived from several sources of research and practice, which can be combined and compared.



Reflect on your Portfolio (Wiki)

Why should teachers engage young people in ethical issues in science lessons?

Reiss and Fuller [22, 23] highlight that “if we accept that science is open-minded, objective, universalist and disinterested, all scientific knowledge is formulated within particular social contexts... the subject matter of science itself – to some extent reflect the interests, motivations and aspirations both of the scientists that carry out such work and of those who fund them. ”

Ethical thinking in secondary school might help students examine ethical and moral implications of using and applying science in life.

The rationale for Problem-solving sequences

The Problem-solving sequence is a step-up from dilemma lessons, designed to help you integrate issues and inquiry processes more deeply into your teaching, as well as applying scientific knowledge.

Like the dilemma lesson, the problem-solving sequence sets up an issue for students to resolve. The difference is that instead of just using an inquiry process, the sequence explicitly teaches the process, all within the context of the issue. To achieve this, the overall issue is divided into two parts, which become the focus for each lesson. Fig 07 shows an example of e-cigarettes:

Lesson 1: Students review the science and consider the evidence.

Lesson 2: Students play a game to learn the inquiry process, and then use it to decide.



How are you going to
make a decision?

Lesson 1

Is there scientific
evidence that
nicotine from vaping
affects people
nearby?

Lesson 2

Are the benefits of
banning indoor
vaping worth the
risks?

decide



SLIDESHARE

– [http://www.](http://www.slideshare.net/)

[slideshare.net/alexandraokada/uk2015a-engage-problem-solving](http://www.slideshare.net/alexandraokada/uk2015a-engage-problem-solving)

Figure 07 – Problem Solving Lesson e-cigarettes - SlideShare

Why is the problem-solving sequence divided into two parts?

Example: In animal testing the issue is “should we ban animal testing for drug development?”, which will be solved during the two lessons.

- **The lesson 1** focuses on a specific context, asthma drugs, which gives the opportunity for students to apply their understanding of the science of breathing, to this new context. Students will be then able to answer if animal testing is essential for drug development.
- **In lesson 2** students learn three ethical thinking processes (utilitarianism, rights and duties, and virtue thinking) to help them come to an informed view. Therefore, students will be able to use ethical thinking to decide about the ban.

The sequence follows a two lesson structure:	
Lesson 1 - science Engage Review – science Consider – evidence	Lesson 2 - skills Re-engage Play Decide



Activity

Explore the Engage materials at engagingscience.eu.

Download one of the SEQUENCE lessons and look at the suggested context, scientific knowledge and teaching approaches.

For example:

1. Animal Testing 2. e-cigarettes



Forum task 3 Lesson Plan (Individual or in Groups)

Post a short comment about the lesson; say which lesson you downloaded and how you think your students would respond to the lesson.

Observe if other participants are interested in the same lesson for group discussion and lesson planning.

3.3 Lesson 1: scientific evidence

ENGAGE presents two objectives:

- **Engage interest**

One of the questions uppermost in students' minds when they enter class is: will this lesson be interesting? The answer will affect how much they engage. So it is worth spending the first few minutes of the lesson engaging students' interest in the Dilemma.

- **Focus students on learning**

It is important to present the goals or learning objectives of the lesson early on so students know what to focus on. In Issue Lessons, there is one objective relating to the use of science content, and one relating to inquiry processes.



Reflect on your Portfolio (Wiki)

What strategies can you use for engaging students' interest and focus on learning?

- **Use the issue as a 'hook'**

Problem-solving sequences start with the context rather than the science. A good context acts a 'hook' to catch students' interest. In Animal Testing, the hook is emotive pictures of furry animals being used as lab subjects.

The hook is designed to raise the Dilemma question in students' minds even before it is presented on the slide. If students are curious about the question, they will be motivated to think about the science and the evidence.

- ***Unfold the learning objectives:***

Having engaged the students, we 'unfold' the learning objectives in steps:

- **provide background information**, to relate the issue to students' existing knowledge, and so they can form an initial opinion based on some facts rather than a knee-jerk reaction;
- **raise a dilemma question**, which will drive students towards finding out the science, consider the evidence, and come to an informed decision;
- **present the objectives**, in such a way that the knowledge answers the students want to find out about.

Unfolding learning goals in this way makes it more likely students will take on the lesson goals as their own, and care about learning them.

REVIEW stage aims to make sense of issues and evidence.

Students need to have prior knowledge of the relevant science concepts. So in this stage you help students recall the key concepts and apply them in an unfamiliar context.



Reflect on your Portfolio (Wiki)

What strategies can you use for helping students review their prior knowledge?

- Ask questions to link context with knowledge
In Animal Testing, the context is developing new drugs for asthma. Asking how the drugs work challenges students to use their knowledge about breathing and gaseous exchange.
- Use the KWL method
KWL is a thinking routine. Students first brainstorm 'what do we Know' to simulate them to recall prior knowledge. They move on to thinking 'what do we Want to know' and brainstorm the information they need to come to a decision the issue. You can then link the answers to the evidence provided in the next stage of the lesson. At the end, they ask 'what did we Learn'?

- Turn recall into activities

Instead of asking direct recall questions, you can create more engaging tasks for students to find out the information themselves from the source material.

Students can represent their knowledge in pictures, conceptual maps or descriptive narrative. For instance, in e-cigarettes students show how particles diffuse and spread to people nearby through visual representation.

CONSIDER stage is a brief discussion stage.

Students think about what they have learned about the science to answer the driving question of lesson 1.



Reflect on your Portfolio (Wiki)

What strategies can you use for helping students consider evidence?

Small group discussion: Students can discuss what they have found out in pairs, or share their findings with the class, ensuring that they give their reasoning and evidence.

Use whole class conversation to reflect on learning: A short plenary helps you determine whether students were able to transfer their knowledge and skills.

During consider stage, students can help peers reflect on how they deal with a science issue.

3.4 Lesson 2: making decisions

RE-ENGAGE stage reinforce students attention.

This stage marks the beginning of the second lesson in the sequence. As students may have forgotten much of what happened previously, it is a good idea to remind them of the key points: the issue, problem-solving question, learning objectives and how this lesson builds on the previous one.



Reflect on your Portfolio (Wiki)

What strategies can you use for reinforcing students attention?

This stage is akin to how TV series begin each episode, with the announcement ‘last week ...’ and show you a potted summary of the key moments to bring your recollections into consciousness. ENGAGE materials do this simply by redisplaying key slides from lesson 1.

Activating the knowledge makes it easier to build on it with new information.

PLAY stage helps students understand a key RRI skills.

Students learn about one part of the decision-making process inquiry through a game or engaging exercise.

ENGAGE teaches about 10 different RRI skills involved in solving problems, making decisions and communicating them:

- | | |
|---|---|
| <ul style="list-style-type: none"> • Interrogate sources • Use ethics • Estimate risks • Examine consequences • Justify opinions | <ul style="list-style-type: none"> • Devise question • Critique claims • Analyse patterns • Communicate ideas • Draw Conclusions |
|---|---|



Reflect on your Portfolio (Wiki)

What strategies can you use for helping students play and practice one of the ten RRI skills?

1. Create a ‘need to know’ the process

The problem-solving approach creates motivation to learn by persuading students there are reasons for knowing skills and content, in order to solve the problem. In this case, it is skills and processes we are teaching.

So we set up a 'need to know' reason by making the decision seem very challenging based on students existing capabilities. Then we introduce a new process as a way to help them make a better decision.

For example, in Animal Testing, we show students how difficult it is to decide about all the arguments for and against using animals. Then we introduce the notion of different ethical thinking strategies.

2. A game to practice using RRI skill

Our approach to getting students to learn the skills is through supported hands-on practice. We use a game, as a motivating way to try out using the skills, in a non-threatening way that gives feedback on the initial attempts and helps students reflect and learn. For example, in Animal Testing, the game puts students into a reality show like 'Survivors' where they are faced with difficult decisions to make. They are told to use different ethical strategies like 'choose the option which benefits most people' (utilitarianism) and see whether they feel happy with their choice.

It may seem surprising that the game deliberately shifts away from the science issue being studied. The reason for this is to do with 'working memory' - the limited store we have to process new information. While working memory can cope with learning a new process, it may well be overloaded if in addition there is unfamiliar scientific evidence to process at the same time. Overloading working memory leads to inefficient learning and confusion.

We avoid this potential problem by setting the game within a context that students will be familiar with, so that no extra load is placed on working memory and students can focus all their resources on learning the new process.

3. Think about the strategies and skills used

Having got students to experience the process, you can now go through the steps involved, to show students clearly what to do, and the thinking involved. To help this process, we provide 'thinking guides'.

Students use the inquiry process to make a decision. For animal testing, it is to identify the ethical thinking strategies used in a range of opinions presented on cards.

- Summarise process in a thinking guide.
- Talk aloud.
- Use the process to make a decision.

Purpose: to help students who are learning a new inquiry process, think it through by breaking it down first into several strategies, and then into individual skills. The thinking guide also provides scaffolding to support students through each one.

Students are given the 1-page thinking guide summarising the steps which the teacher explains with a ‘think aloud’.

Activating the knowledge makes it easier to build on it with new information.

Why thinking-guides?

Effective skills teaching means first breaking down complex RRI skills into small parts. To identify these, we have done a task analysis of each process.

For instance, a task such as ‘evaluating a media article’ can be decomposed into 3 strategies:

- Judge the reliability of the source,
- Check for bias,
- Evaluate evidence for the claim.

Each strategy can be further broken down - until you reach a set of thinking steps, which inexperienced students can follow, along with the underlying concepts students need to become familiar with.

Skills for the strategy of ‘judge the reliability of the source’

- Judge whether:
 - The authors of the research are qualified scientists.
 - The research was published in a peer-reviewed journal.
 - The research is recent or not.

Concepts and terminology

- Peer reviewed, where research is checked by other scientists.
- Bias, when an experimenter affects the outcome of the experiment, or when a journalist favours a point of view.
- Funder who pays for scientific research.
- Journal, a magazine which publishes science research for others to read.

In the literature, this approach is called a ‘cognitive strategy’ - what students follow when they don’t know how to do the skill yet. Such a scaffolding strategy has been proven highly effective in teaching reading, writing and problem solving.

What we provide

ENGAGE provides these thinking guides in the form of 1-page visual organisers.

Thinking guides are designed to be simple to use, give clear guidance and examples in accessible language. They include definitions of the concepts and key terminology students need to learn.

Thinking Guide - analyse patterns

To give an example, for ‘Analyse Patterns’ (Fig. 08), the Thinking Guide is a flowchart with worked examples to help students through the process of deciding how to interpret data and spot patterns from charts and graphs.

analyse patterns



Use this thinking guide to compare **categoric variables** in bar charts, pie charts and Sankey diagrams.

Worked examples

describe the PATTERN

Summarise what the chart shows.

give NUMBERS

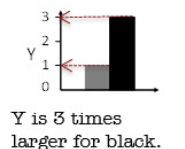
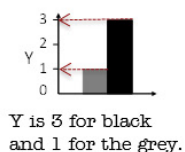
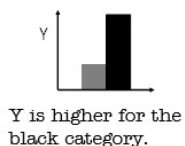
Add values to illustrate any **differences**.

COMPARE numbers

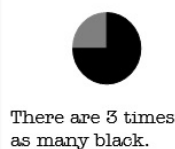
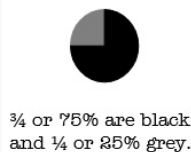
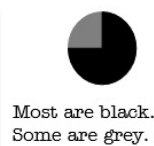
Say how many times larger 1 value is than another.

suggest REASONS

Use scientific ideas to suggest reasons for any **differences**.



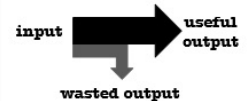
Y may be 3 times larger for black because...



Reasons are not usually needed



The input energy is... and the useful and wasted outputs are...



$\frac{3}{4}$ or 75% is useful and $\frac{1}{4}$ or 25% is wasted.



The useful output is 3 times as big as the wasted output, or

$$\text{Efficiency} = \frac{\text{useful output}}{\text{total input}} \times 100\%$$

You may want to comment on the efficiency.

Figure 08 – Problem Solving Lesson - Patterns SlideShare

LESSON 2 - DECIDE stage is where students, armed with knowledge and evidence from the previous stages.

They use the targeted inquiry process to come to a decision and communicate their thinking.

In Animal Testing, this means putting to use the ethical thinking strategies previously taught in deciding whether to ban testing on animals for drug development.



Reflect on your Portfolio (Wiki)

What strategies can you use for deciding their evidence-based opinions?

1. **Class conversations**

We recommend some form of discussion where students share and compare views. The discussion strategy is the subject of another Tool.

2. **Create an authentic performance out of the decision**

An authentic performance is one where students articulate their viewpoint for an authentic purpose closely resembling the actual situation. An authentic performance maintains the realism and engagement of the authentic task. Having a specific audience gives purpose to the writing, and challenges students to learn how to communicate in different ways. The brief should always clarify what students should include in their answer, such as the evidence, and reasoning behind their decision.

3. **Expose students to wider arguments with source material**

Student can come to decisions using arguments they have thought up, or those of other students. Often there will be important arguments they do not come up with. Having the key arguments written down makes the task of weighing them up easier, and quicker.

4. **Plenary to reflect on how students did**

You want to know that students have not only completed the task but have engaged in the thinking, using their knowledge and inquiry skills. You can ask selected students to report back their decisions and reasoning,

It is valuable to get students to reflect on whether they changed their views from the beginning of the sequence, as a result of learning a process for decision making and applying their knowledge to consider the evidence.

The plenary should be kept brief so that students remain engaged.




Forum task 3 - Lesson Plan (Individual or in Groups)

- Using your downloaded lesson as an example, how would you hook the students into the activity?
- How will you ensure students reach a solution to the problem?
- What do you see as the biggest challenge for you address in this approach to inquiry?

3.5 Teachers' strategies

The table shows the rationale for each lesson, stage-by-stage in each lesson, giving examples from Animal Testing.


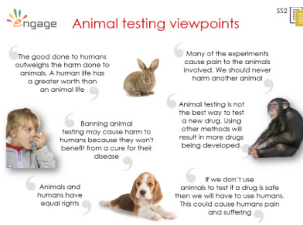

LESSON 1:

Stage	Rationale	What could happen/how do you do it? (with examples from Animal Testing)
Engage	<p>The first purpose is to create interest - similar to dilemma lesson. This is done in several ways:</p> <p>1) using emotive images, and allowing students to react to them.</p>	 <p>Set up the context for the issue e.g. emotive images of how animals are used in drug development, and then a list of reasons why scientists need animal testing.</p>

LESSON 1:

Stage	Rationale	What could happen/how do you do it? (with examples from Animal Testing)
Engage	<p>2) By giving an overview of the issue, so students can think more rationally about their view.</p> <p>3) Getting students to articulate their first, intuitive view, so that they can compare this with others, and use this as a basis for later reflection after they know more.</p> <p>Pose the issue question</p> <p>Set the learning objectives</p> <p>Clarify the lesson structure</p>	<p>A new drug is tested on:</p> <p>1 Human cells to see if it has an effect.</p> <p>2 Animals to check if it safe and works in a whole organism.</p> <p>3 Humans to find out if it helps the illness.</p> <p>Engage Review Consider</p> <p>How are you going to make a decision?</p> <p>Lesson 1 Use scientific evidence to answer: Is animal testing essential to drug development?</p> <p>Lesson 2 Use ethical thinking to answer: Is animal testing right or wrong?</p> <p>Will you sign the petition?</p> <p>Explain why.</p> <p>In these lessons you will :</p> <p>Breathing: Lesson 1</p> <ul style="list-style-type: none"> show how asthma affects the structure of the gas exchange system <p>Consider viewpoints: Lesson 2</p> <ul style="list-style-type: none"> learn 3 kinds of ethical thinking to make decisions: <ul style="list-style-type: none"> utilitarianism, rights and duties, virtues <p>Using these, you can lead students towards the issue question, or get them to suggest what the issue is. Get them to commit to being for/ against initially, so that you can ask for their reasons, and look for a change of opinion later.</p> <p>You can make clear how the lessons are split to focus on one objective at a time - first to apply the science, and then to consider how to make a decision.</p> <p>The learning objectives are best presented when students already appreciate the issue, and have some motivation to resolve it.</p>
Review	Apply science	<p>Thousands of children have asthma. Drugs help but are not always effective. Scientists need to create more.</p> <p>Is animal testing essential to asthma drug development?</p> <p>Find out how asthma affects the body and how the drugs work.</p> <p>Engage Review Consider</p> <p>Explore the scientific facts and ideas behind the issue</p> <p>In Animal Testing, the issue is specifically related to the topic of breathing, by looking at the issue of creating asthma drugs.</p> <p>Students apply existing knowledge to how asthma affects breathing.</p>
Consider	Consider the scientific evidence	<p>Animal testing evidence</p> <p>Organ-on-chips have been developed for some organs. They can be used to check that drugs work without using an animal.</p> <p>Inhalers, and nearly every other medical breakthrough in the last 100 years, has resulted directly from research using animals.</p> <p>Every species of animal is different. A drug that works in an animal may not work in a human.</p> <p>Computer models and human cells are also used to test new drugs.</p> <p>This stage allows students to answer the lesson 1 question, by looking at the scientific evidence for the importance of animal testing.</p> <p>In Animal testing, it is presented as summaries of relevant research findings on cards, for students to consider the importance.</p>

LESSON 2:

Stage	Purpose	What could happen/how do you do it?
Engage	Recap previous lesson.	The issue and key points from lesson 1 are reviewed to activate students' existing knowledge.
Play	<p>Experience the decision making/inquiry process.</p> <p>Reflect on how to use the process.</p>	 <p>We use games as an engaging teaching approach for introducing students to whichever aspect of decision making - ie inquiry process that we are trying to teach.</p> <p>Introducing the skill and its concepts in a familiar context (rather than in a complex scientific context) makes it a lower demand and easier for students to grasp.</p> <p>A plenary slide ensures that students think about the experience, and draw out the key parts of the process. In Animal testing, they reflect on 3 different thinking strategies they used for making a decision in the game.</p>
Decide	<p>Summarise process in a thinking guide.</p> <p>Use the process to make a decision.</p> <p>Further practice with the inquiry process.</p>	<p>Students are given a 'thinking guide' (see section below) which summarises the steps in the inquiry process visually.</p>  <p>Students use the inquiry process to make a decision. For animal testing, it is to identify the ethical thinking strategies used in a range of opinions presented on cards.</p> <p>Ideally, students should get further practice in using the process. In Animal Testing, there is a follow-up issue students are posed:</p> 

Hypothesise

1 State observation in detail What did you see happen?

2. Suggest a hypothesis What is your **hypothesis**? What science idea can back it up?

My hypothesis for why it happened is

The science idea to back up my explanation is

..... means that ... (the science idea)

3. Make experimental prediction If you do an experiment to test your idea, what do you **predict** will happen?

If my idea is correct, and I do an experiment to

.....

Then, I predict what will happen is...

4. Conclude if hypothesis correct What did you find out? What can you **conclude**?

In my test, I found that...

I can conclude that my idea is because ...

Key Words **Observe** – something you see (or hear or smell)
Hypothesis – possible explanation which you will test

Predict – what you expect to happen
Conclude – what you decide

Figure 09 – Problem Solving Thinking Guides - SlideShare

Cognitive strategies – are the specific methods that participants use to solve problems, including all sorts of reasoning, planning and decision making

Effective skills teaching means first breaking down complex RRI skills into small chunks. Each can be further broken down - until you reach a set of thinking steps which an inexperienced student can follow. This is a '**cognitive strategy**' - what students follow when they don't know how to do the skill yet.

Thinking Guides for problem-solving (Fig. 09) scaffold the thinking for each RRI skill. These help students with their initial practice until they become more confident and independent.



CHAPTER 4 conversation

The aims of this Tool are to show how to:

1. prepare students for class discussions using problem-solving material exemplars (e-cigarettes or animal testing).
2. use effective discussion formats to help students articulate, share and reflect on their opinions.
3. develop students' ability to argue with evidence, using an argumentation framework.
4. manage the discussion and students'.

SUMMARY

- **Conversation** in ENGAGE context refers to a whole class debate regarding an RRI (or socio-scientific dilemma) facilitated by the teacher.
- Students can develop argumentation and evidence-based solutions supported by the class conversation: address their 'need to know', consider evidence to develop initial opinion, construct and articulate arguments to justify their conclusions
- Five strategies can be used separately or integrated for effective conversation: preparation, fishbowl, evidence-based dialogue map, class participation, management techniques
- Scientific argumentation is the process that shows how conclusions can be reached through scientific reasoning.
- Its key components are: claim, evidence, reasoning (questions, ideas, pros, cons, data)
- Some strategies for students develop argumentative thinking:
 1. students review the details and concepts to solve a problem
 2. they move then beyond the concept, and looking at the evidence
 3. students have the background knowledge and evidence to formulate arguments for the discussion.
 4. they have learned about specific RRI skills (e.g. what the risks and benefits)
 5. evidence and reasoning from the previous activities is the basis for discussion and key factors for reaching evidence-based conclusion

4.1 Introduction

This chapter presents conversation tool, its benefits, challenges and strategies. In class conversations devoted to learning scientific content, talk is teacher dominated. In teaching issues, the emphasis is as much on student-student interactions, so that students can learn how to express their views and develop their ability to argue and think critically.

Conversation in ENGAGE context refers to a whole class debate regarding an RRI (or socio-scientific dilemma) facilitated by the teacher.

It is based on three steps for supporting students to develop argumentation and evidence-based solutions, so they will:

1. review the scientific ideas to address their 'need to know'.
2. consider how the concepts build into evidence to develop an initial opinion.
3. construct and articulate arguments to justify their conclusions.

4.2 Conversation lessons

The difference between Group discussion and Conversation is that group discussion is in small teams of students, in which peers discuss more autonomously by using a template or guidelines. The teacher's role is to listen, observe and answer any of their questions. While conversation refers to the whole class discussion, so a teacher can model the argumentative debate, and manage contributions to enhance the argumentation skills by scaffolding the scientific thinking: what is the evidence? What are the counterarguments? What are the common opinions? What is the overall feedback? Both strategies can be used during problem-solving lessons.

Why teacher-led whole class discussion?

In the Discussions tool, we set out benefits of students engaging in discussion. In this tool, the focus shifts away from small groups towards whole class discussion, facilitated by the teacher. There are several benefits of this type of discussion, over and above those of small group discussion. Teachers can use conversation to:

1. Help students develop their argumentation and critical thinking skills through modelling and guiding.
2. Show the provisional nature of science knowledge and the importance of evidence-based argument in complex socio-scientific issues.
3. Emphasise the controversy by drawing out a range of views
4. Help students reflect on their opinions collaboratively and become open to changing their views in the light of other arguments or evidence.

Four important reasons why teachers are reluctant to use whole class discussions are:

1. **Uncertain learning:** Although, some teachers question the value of discussion given the pressure to get through the curriculum, many acknowledge that talking shapes thinking - students can learn great deal from articulating their understanding, and responding to other students' ideas.
2. **Lack of engagement:** In a large group of 25+ it can be very difficult to keep all the students engaged. Each student has a limited opportunity to contribute, and when not involved it is easy for students to become passive, for their attention to wander which can lead to off-task activity and behaviour issues.
3. **Student reticence:** Many students do not feel comfortable contributing in a large group, either because they are not confident about what they have to say, are intimidated by the size of the audience, because they are afraid of being wrong or worried about being challenged in their views.
4. **Loss of control:** Class discussion can get noisy and go off in all kinds of unanticipated directions, which can be threatening to some teachers who are used to being in control of the direction of the lesson at all times.



Reflect

Think about the difference between small group discussion and whole class discussion. From your personal perspective what do you see as the key purpose of conversation in the classroom? How would you apply conversation in your lesson? How do you face the challenge of whole class discussion?

4.3 Teachers' strategies

We have designed a strategy to overcome each obstacle:

Strategy	Which discussion obstacle(s) it helps primarily
1. Preparation activities	Uncertain learning
2. Fishbowl format	Student reticence/Lack of engagement/Loss of control
3. Evidence-based dialogue mapping	Visualising argumentation related to the whole debate
4. Active participation strategies	Student reticence/Lack of engagement/Loss of control
5. Management Technique	Teacher observe and control key issues: participation, time, behaviour, ...

ENGAGE recommends five strategies for achieving effective discussions, which are the main content of the Tool:

- 1. Preparation activities:** these are described with a commentary on an exemplar ADAPT material. The activities take students through the stages of building knowledge and using that to construct arguments.
- 2. The Fishbowl format:** this structured discussion format, where only half the class are discussing, and the other half listening and analysing, acts as a transition between the easier small group discussions to the more challenging whole class discussions and debates.
- 3. Dialogue Mapping:** is a graphical representation created by the teacher during the conversation to build shared understanding among students. It is based on four core elements Question, Idea, Pro/Con and evidence nodes that grow with the conversation ^[25].

4. Class participation: principles and strategies for securing student participation in whole class discussion, using ground rules, clear roles for the teacher, and training for students in the skills to contribute in different ways.

5. Management techniques: best practice advice for setting up, opening, closing and dealing with tricky situations.

I. PREPARATION ACTIVITIES

Questioning Sequences in the Classroom

ENGAGE Advanced Materials follow an approach called ‘Questioning Sequences in the Classroom’ (Marzano and Simms). This is designed to systematically prepare students before a discussion, so they are less likely to feel reticent about contributing, and the discussion itself is more likely to stay on track.

Questioning Sequences starts by getting students to review or build the basic knowledge, then connect these into bigger ideas, and finally at the claims, evidence and reasoning. All of this happens in a small setting, with students working individually, in pairs or in small groups, before the whole class discussion itself - a culmination of all the activity. Below are set out the stages in Questioning Sequences:

Stage 1: Facts and concepts

Details are the building blocks of complex ideas, and we need to draw out and develop students’ knowledge before they can use it to create arguments. So the questions at this stage are designed to activate or provide students with the essential background knowledge. For instance, if the discussion is going to be about pros and cons of artificial replacement hearts, the detail questions would be about the workings of the heart.

Stage 2: Ideas and evidence

Here, questions help students organise the facts and concepts from stage 1 into bigger ideas and evidence.

- *Ideas:* students group the scientific details into larger, more abstract categories and comparing within and between categories.
- *Evidence:* students select the important data/findings which are relevant.

After stage 2, students have the background knowledge and evidence to formulate arguments for the discussion.



Scientific argumentation – is the process that shows how conclusions can be reached through scientific reasoning; that is, claims based, on evidence. It includes debate, dialogue, conversation, and persuasion.

Figure 10 below describe the parts of the CER framework with the rebuttal.

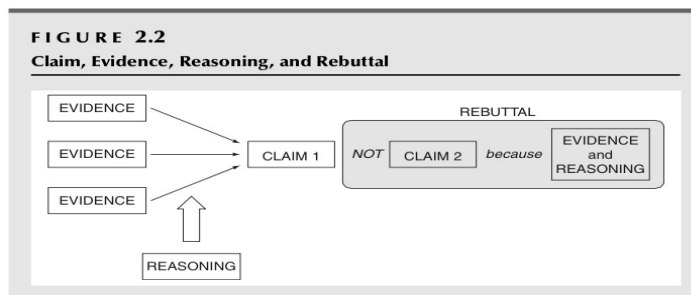


Figure 10 – CER framework

The CER Framework is taught explicitly as our ‘Justify opinions’ Inquiry process, which is the focus of several problem-solving materials. There is a ‘Thinking Guide’ on ‘Justify opinions’ to scaffold students thinking as they practice constructing arguments.



Reflect on your Portfolio (Wiki)

How could teachers help students construct arguments?

How could teachers support ethical thinking?

Extra exercise for your wiki Portfolio

Duncan finds out that he has the allele for Huntington’s disorder. His wife Sarah is pregnant. Sarah’s fetus can be tested after 15 weeks of pregnancy. If it is positive then Sarah can have a termination. (Reiss, 2009)

Nikki: There is a chance of having a miscarriage after this test, so you could lose a healthy baby

Ruth: Having a termination after 15 weeks of pregnancy is a very hard decision to make

Mark: People with disabilities need a lot of support. This support costs money

William: A person with Huntington’s disorder is healthy for most of their life before they get any symptoms

Tony: It’s wrong to take a human life even if they have a disability

Who is making an ethical point?

Who is concerned about the safety of the test?

Who is thinking about the economic effect on society?

(Source: Reiss, 2009)

ENGAGE exemplar with commentary

The preparation strategy, based on questioning sequences and the argumentation framework, is embedded in ENGAGE Advanced Materials (ADAPT). They are designed to make it easy to implement the approaches, by providing:

- Two ready-made lesson materials based around a simple, 3 part lesson structure (see problem-solving sequence Tool)
- An opportunity for a whole class discussion in lesson 2, after a series of specific preparation tasks, together with all the information students need

To explain how to put the preparation strategy into practice, we will give a detailed commentary on one of the Advanced Materials: e-cigarettes.

In e-cigarettes, students discuss the issue of whether smoking these electronic cigarettes, or ‘vaping’, is really safe. To focus discussion, they will come to an informed opinion of whether or not to support a European ban on vaping at work. The tasks described below follow the stages of the Questioning Sequence:

Stage in Questioning Sequence	Purpose	E-cigs	What could happen/how do you do it? (with examples from e-cigarettes)
Stage 1: Facts and concepts	Create a need to know for students to review the scientific ideas	Review	The overall question for lesson 1 is: “can nicotine from vaping affect people nearby”. This creates a ‘need to know’ for students, which is broken down into the two stages. In stage 1, students review the details and concepts relating to nicotine particle behaviour as they find out how e-cigarettes work.
Stage 2: Ideas and evidence	Students consider how the concepts build into evidence	Consider	The second task in lesson 1 is for students to consider the likelihood of whether exhaled nicotine can reach people nearby, based on the information from Stage 1. In other words, they are moving beyond the concept, and looking at the evidence for ‘passive vaping’. After stage 2, students have the background knowledge and evidence to formulate arguments for the discussion.

Stage in Questioning Sequence	Purpose	E-cigs	What could happen/how do you do it? (with examples from e-cigarettes)
Stage 3: scientific argument	Students construct and articulate arguments	Decide	This is the last stage of lesson 2, where students have learned about what the risks and benefits of vaping are, and need to weigh them up. Clearly, students may do this differently, leading to different viewpoints on whether to ban vaping. This difference - backed up by evidence and reasoning from the previous activities, is the basis for discussion.

II. FISHBOWL FORMAT

The Fishbowl is so called because a group of students seated inside a circle of chairs (the fishbowl), discusses an issue while other students sitting outside the bowl watch and listen. After the discussion, the teacher leads a secondary discussion about what happened, and then another group goes inside the bowl.

The Fishbowl can reduce student reticence about talking, because it feels like a small group. It also keeps everyone engaged because the observers are not passive, but actively listening and analysing what is being said, knowing their turn is next. This format can act as a transition between small group discussion (see chapter 2) and the more challenging whole class discussion. The Fishbowl also allow students to practice a skill under peer review and receive feedback.

From the teacher's point of view, it is easier to manage than a whole class discussion, as less than half the class is actually discussing at any one time.

III. ACTIVE PARTICIPATION STRATEGIES

It is possible to keep all students engaged in a whole class discussion, by making use of these strategies for active participation:

- Expectations for student participation.
- Taking a facilitator role
- Moving from small groups to whole class discussion

Expectations for student participation

Here is a set of guidelines to share with students so they know what is expected of them:

- Everyone is expected to participate, by contributing at some point in the discussion

- Domination of the conversation by one or two students is not acceptable
- Let people finish their contribution, do not interrupt
- Listen and concentrate on what others are saying, not thinking how you will respond
- Keep what you say relevant to the issue question
- You can challenge a view with evidence, but don't make it personal

Taking a **facilitator role**

This role means you are steering and guiding the discussion, but not dominating the conversation. Students may naturally look to the teacher to validate their responses, and it is important to direct responses to others in the class to build support or challenge ideas. You are also modelling ways of contributing to the discussion which students can learn to take themselves. Here are a series of prompts for questions to achieve different purposes and ways of modelling discussion behaviours:



Facilitator role – in decision-making refers to the process of designing and running a successful conversation that help students develop scientific augmentation.

a) *To get reasoned arguments:* make two columns on the board: Claim 1 and Claim 2 and collect the evidence under each claim. Ask questions like: Can you elaborate on...? What do you mean by...? Can you be more specific? Can you tell more about...

b) *To get rebuttals* Ask: who thinks differently? Who disagree with this claim? why? Model the use of the sentence: I disagree with the claim provided by Because(rebuttal).

c) *To keep the conversation moving forward:* summarise what has been said, by whom, and then invite students to offer further views by asking: Does anyone have a totally different claim?

d) *To get evaluation of the evidence* ask: Is this a valid argument? why? Can you give us an example from the information that was given to you? What is the source of the information presented here? Do we think we have enough evidence to support the claim?

e) *To liven up the debate:* play 'devil's advocate' by deliberately expressing a viewpoint you think students will want to argue with, to encourage students to provide a rebuttal. Or, be open and argue for the view you really

believe in, while acknowledging that it is just an opinion.

f) *To get students to reflect on their own view:* present a slightly different situation, and ask the students: would you still think that?

g) *To get students to disagree respectfully:* when students say something inappropriate, model a more acceptable response. E.g. instead of: 'that doesn't make sense', say 'I don't think I agree. Could you explain? Instead of 'that is a dumb opinion', say 'I see it differently because'. Or, instead of 'you are dead wrong', say 'have you considered?'.



Reflect on your Portfolio (Wiki)

What are the key roles for teachers to support problem-solving lesson with conversation?

Extra activity

Practicing a real argumentation-based conversation

- Select a strategy for a whole class debate (e.g. fishbowl)
- Select key questions and key statements from previous lesson plan to initiate the debate with participants (volunteers) who can comment on the statements selected and provide an example for others.
- Tutors will use LiteMap as a wall board to map the participants' contributions (claim / evidence x rebuttal / evidence)
- This can be also practiced during our webinar 2 Sequences

Moving from groups to whole class discussion

One way to achieve active participation from the whole group is to start the discussion in small groups, and then move to a whole class setting. Here is one way to manage this transition:

1. Each group comes to a consensus on their point of view and main arguments. One student can be assigned as the spokesperson and the others can add/support.
2. Each group prepares a very draft poster with their argument, and the groups place the poster on the board as the spokesperson presents the group's arguments.
3. During this process, the teacher can either:
 - (a) allow 2-3 questions/comments from other students while each group presents, or
 - (b) not allow any questions.
4. After all the presentations, the groups can "attack" each other's arguments by asking questions.

IV. Evidence-based dialogue mapping

Conversations can be framed through a graphical representation (Fig 21): an opening question (dilemma), which sets the context (and to a degree establishes the scope that might be addressed). An Idea (= Toulmin Claim) can be students' opinions that respond to the Question while arguments are expressed as Pros (= Warrant) that supports the Idea, and counterarguments are expressed as Cons (= Rebuttal) that challenge the Idea. To highlight the need for explicit evidence to back a Pro or Con (in order to pre-empt arguments that are a mere opinion), we introduce the Data node. A Pro or Con node might initially summarise in its label what in Toulmin scheme would be the Warrant, plus, optionally, Backing (e.g. Data), which refers to the evidence.



Figure 11 – Evidence-based dialogue map

In scientific reasoning, it is important that pupils can ground their claims in scientific concepts rather than personal convictions. The quality of their arguments is also better if they can connect not only supporting arguments, but also counterarguments (thus resisting confirmation bias), and data as backing for claims ^[26].

In Toulmin's scheme:

1. **Claim** is the position on the issue and the essence of the argument.
2. **Data** are grounds for the argument serving as evidence that can be accepted as factually true.
3. **Warrant** is the reasoning that supports the connection between the data and the claim. Argumentation research has since identified many different kinds of warrant (cf. Walton's work on presumptive reasoning schemes).

When teachers introduce scientific reasoning to school pupils, Simon et al. (2002) argue the need to highlight some basic differences between “motivational” arguments (i.e. based merely on convictions), “authoritative” (an argument by expert opinion), and more “substantive” arguments (e.g. based on example, classification, generalization or cause and consequence).

4. **Rebuttal** states the exceptions to the claim and is an exception to the truthfulness of the argument.

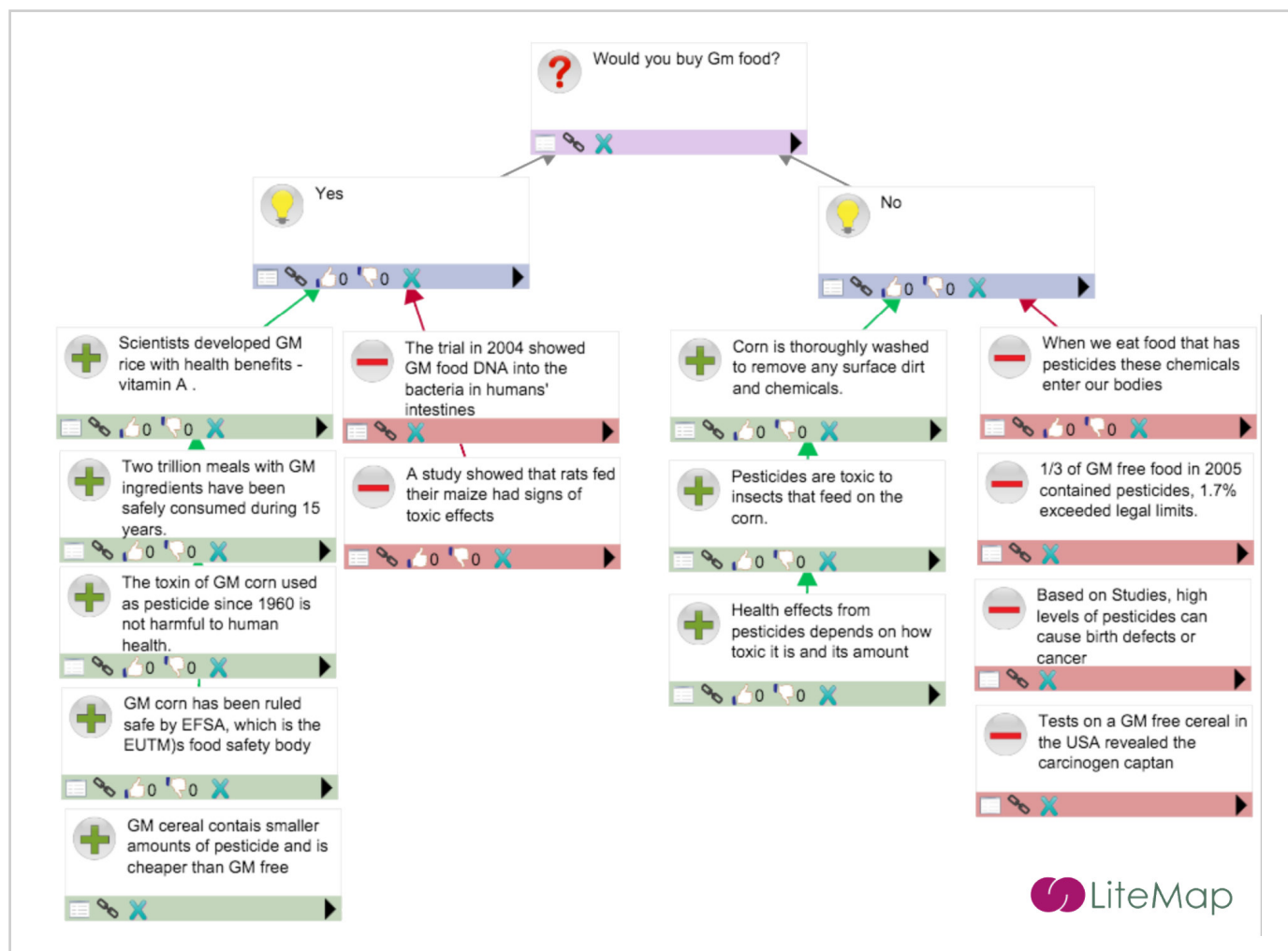


Figure 12 – GM decision - LiteMap of the discussion

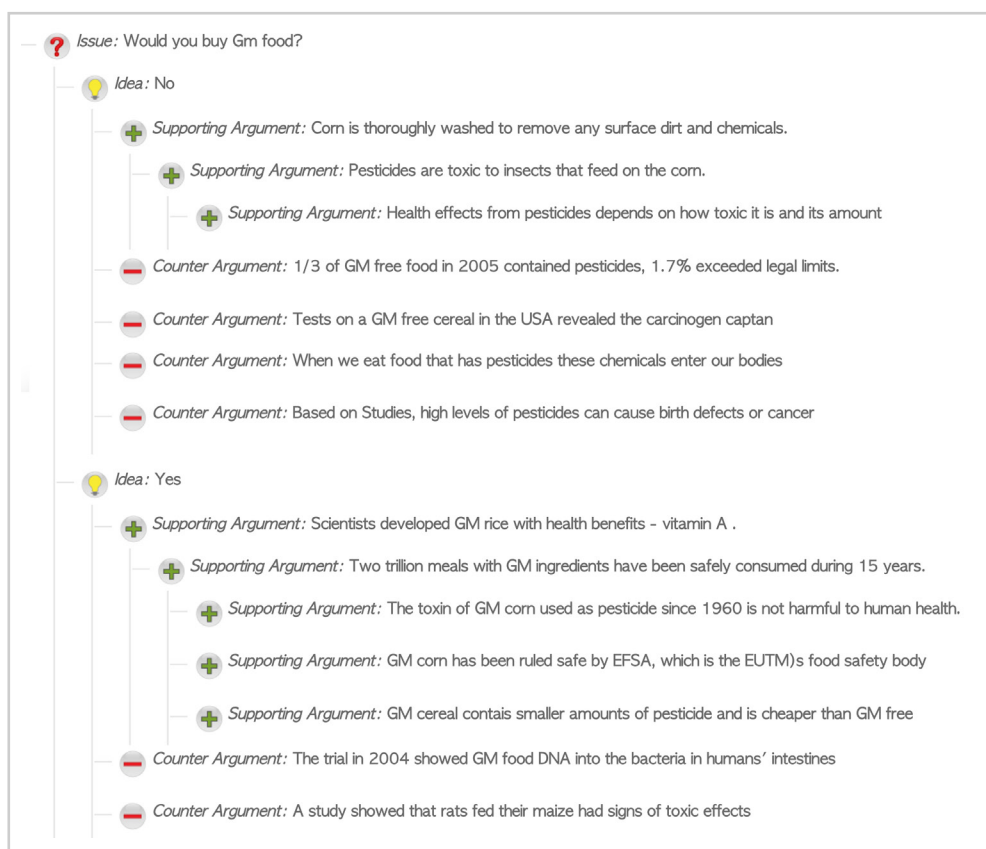


Figure 13 – Statements for writing informed based opinions in LiteMap

Teachers' role:

Teachers play an important role in capturing the conversation by using dialogue maps to make the argumentative debate clear for the whole class. To facilitate this process, teachers can use software for dialogue mapping, for example, Compendium software tool or the LiteMap web application. A digital map of the debate can be created by letting students share their contributions.

Another way to capture the conversation is to stick Post-its to the wall, using various colours to represent the argument components, (e.g. pink-question, yellow-idea, green-pro, red-cons and white-evidence).

Students' participation:

When Students can visualise the argumentation developing through the conversation, they can distinguish strong claims i.e. those with more evidence from weaker ones. Claims with poor argumentation can then be improved. At the end, the map can be used to structure students' scientific writing.

V. Management Technique

It refers to best practice advice for setting up, opening, closing and dealing with tricky situations. **Issues to be managed:** Time, participation (engagement), knowledge understanding, inquiry skills (e.g. argumentation) and learning outcomes through assessment.

The screenshot shows the Engage software interface. On the left, there is a green box with the question: "Will you support a European ban on indoor vaping in public places?". Below this is a red circle with a diagonal line through it, over a cigarette icon. To the right is a form with the following sections: "I support / do not support the ban.", "The benefits of the ban are", "The risks of the ban are", and "Overall, I think that the risks/benefits outweigh the risks/benefits because". A red pen is shown writing on the form. At the bottom, there is a navigation bar with three buttons: "Engage", "Play", and "Decide". The "Decide" button is highlighted in orange. In the top right corner, there is a small icon of a document with the text "SS2" and a small icon of a document with the text "20".

Figure 14 – Informed-based opinion report

Task4: Applying problem-solving with Conversation in your lesson

Assignment2: Report on your practice

Post your guidelines for whole class discussion and conversation (easiest to copy and paste into the message).

1. Write down the ENGAGE material that you selected.
2. Describe the Conversation, method(s) used and your role
3. Report on student's achievements and include challenges and outcomes

RRI links

Matteo Merzagora and Vanessa Mignan

The concept of Responsible Research and Innovation was introduced in order to reframe the way in which science is embedded in society. Formal and informal education obviously play a crucial role in this sense. In the Engage project vision, the following aspects are considered essential in order for science education to respond to the Responsible Research and Education challenges:

- present science in relation to its social, economic and ethical consequences in a larger social context;
- focus on current, cutting edge research in order to understand the relevance of science in contemporary world, but also as a way to motivate students for learning school science;
- create links with other key actors such as researchers, informal science education institutions such as science centres and science festivals, the media, the innovation and creative sectors, the industrial sector.

The following books, online reports and papers allow us to understand the meaning of Responsible Research And Innovation.

Books:

Novotny H, Scott P and Gibbons M. (2001) *Re-thinking science: knowledge and the public in an age of uncertainty*, Polity Press, Cambridge

Ziman, J. (2000) *Real science: What it is and what it means*, Cambridge University press

Massimiano, B. (2004) *Science in Society. An Introduction to Social Studies of Science*, Routledge,

Whitmarsh, L. and Kean S. (2005) *Connecting Science, What we know and what we don't know about science in society*

Chittenden D., Farmelo G. & Lewenstein B.V. (Eds) (2004) *Creating connections. Museums and the public Understanding of current research*, Altamira press, Walnut Creek

Wilsdon, J. and Willis, R., *See through science*, Demos, London, 2004.

Reports and Papers:

Title	Description	Highlights and comments
European Union (2012) Responsible research and Innovation: Europe's ability to respond to societal challenges, Brussels, European Union.	A synthetic definition of Responsible Research and Innovation from the point of view of the European Commission.	This four-page leaflet is an introduction to RRI. The main keys are described in synthetic and effective way: engagement, gender equality, ethics, science education and open access.
Ryan, C. (2015) Science Education for Responsible Citizenship. Report to The European Commission.	This publication on science education offers a 21st century vision for science for society within the broader European agenda.	This report presents problems and challenges and recommendations in science education for responsible citizenship
European Commission (2013) Special Eurobarometer 40.1 : Responsible Research and Innovation, Science and Technology	The report presents the results of a large survey on Responsible Research and Innovation among European citizens.	How does the public – including students – perceive the RRI keys? Are there national differences? Do these concept change depending on the profile of the EU citizen?
European Commission (2014) Special Eurobarometer 419. Public Perceptions of Science, Research, and Innovation	The report presents the results of a large survey on the way science and technology is perceived by the general public.	This report allows to take into account the way in which the European citizens perceive scientific advancements.
J. Osborne and J. Dillon (2008) Science education in Europe: Critical reflections: A report to the Nuffield Foundation, London: Nuffield Foundation	A report of two European seminars organised by the Nuffield foundation to analyse science education in Europe.	This report focuses on RRI, highlighting the reason why science education today needs to evolve in order to respond to the dramatic changes of science in society.
Ulrike Felt et al. (2013) Science in Society: Caring for our future in turbulent times, European Science Foundation,	A study commissioned by the European Science Foundation on the current relationship between science and society.	The report start by analysing the major reordering in science-society relations that is occurring in the present times, also considering factors such as the economic crisis, and link this with research and innovation.
François Taddei (2009), Training creative and collaborative knowledge-builders : a major challenge for 21st century education, OECD Report.	An inspiring document on “training through research”, commissioned by the OECD.	It focuses in particular on the role and the importance of creativity, the capacity of flexible and adaptive thinking and links between the way scientific research is conducted in contemporary world
Ulrike Felt, Brian Wynne, Taking European knowledge society seriously, Directorate-General for Research, Science, Economy and Society EUR 22700, 2007.	The report analyses the transition toward a knowledge society and its relationships between science and society, role of science education and science communication.	For the context of science education, the analysis of the facts-opinion-values connected to science is interesting.

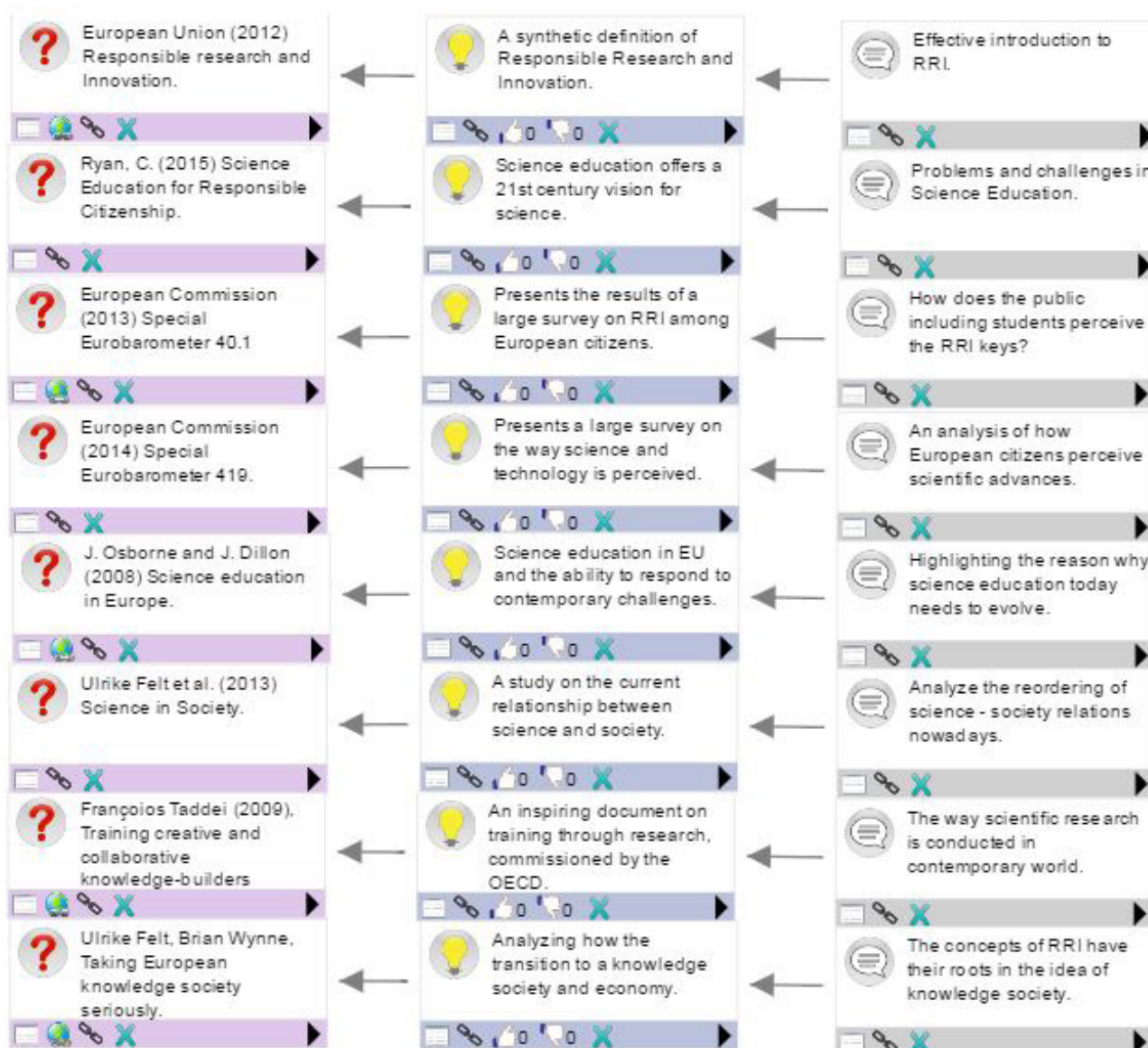


Figure 15 – RRI references - LiteMap

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Course guidelines

We hope that you will enjoy this online mini course, which offers you an in-depth understanding of four ENGAGE tools: Productive Dilemma, Group-Discussion, Problem-Solving and Conversation. We will discuss how to use these tools for enriching your Science lessons with ENGAGE materials. This is will create opportunities for students to use their science knowledge and develop specific inquiry based learning skills. Some suggestions and guidelines:

- You can access the content (PDF, Slides, and Video) of this course on your mobile device or computer.
- The course blends **off-line activities**: reading, planning, teaching a lesson and annotating your reflections and **online activities**: videoclips, discussions, summary and feedback provided by tutor and peers
- **Optional activities**: exciting web conferences, extra articles and research interview.

Course content

The ENGAGE course is based on objective information and visual content through video & slide presentations. You can access full view of these resources by clicking on the respective icon.

Our activities

ENGAGE activities include discussion forums and webinars. In the forums you can reply or comment on posts or add a new post about a different topic. If you cannot attend a webinar, the replay or a summary will be available for your comments.

Our assignments

The ENGAGE assignment is based on “reflection – action – reflection” (plan – do – review). First, we will ask you to select a dilemma activity (week

1) and a problem-solving activity (week 3) in EngagingScience.eu to plan **how you would use group discussion methods and conversation strategies** to introduce and use the materials. WE will ask you to reflect on the teachers' roles and discuss the following questions:

- What **challenges might** you face?
- What **strategies will you use** to teach the lesson?
- What do you anticipate the **pupils will achieve** from the lesson?

Second, after discussing your lesson plans with tutor(s) and colleague(s), we invite you to **teach the lesson to one of your classes** (during week 2 and/or week 4). If this is not possible so please at least try to use it with a group of colleagues or participate in our interactive webinars. Third, you can then **report on your experiences** in the final Assignment (week 5 or week 6) about: a. planning, b. strategies, c. challenges, d. intended outcomes, e. unexpected results.

Certificate of 30 hours

The minimum criteria to obtain the UK Certificate about Engaging Science: 1. Contributing to the Forums. 2. Participating in one webinar. 3. Completing the final assignment.

Next Steps

ENGAGE will offer a special European Merit Certificate for those participants who complete all assignments of courses including pre and post course surveys. For those who complete the course successfully can then apply to work in the ENGAGE Project as an expert teacher by joining the next team of tutors. If you have any questions or issues about the course please share them in the discussion forum.

COURSE OUTLINE

The ENGAGE course was designed to offer flexibility to all participants, for those who would like to complete the course in four or six weeks. Tutors will also share weekly summaries for participants with an overview of the activities, interactions, relevant collaborations and key information. They will also establish dates for webinars, but in case you miss the online meeting, you can replay it and contribute to the respective discussion forum. Please reply our two surveys, we can then improve the course to address your interests. In case of any technical problems, enter in contact with your tutor by email and describe your problems.

6 weeks course - Introduction

- Course Information and overview
- Survey: Please Share your interests
- Coffee break: Knowing each other
- Videoclip: ENGAGE Lesson
- Webinar: Engaging Science

Week1: Dilemma Lesson

- Slides: Dilemma
- Forum: Topical Material

Week2: Group Discussion

- Slides: Group Discussion
- Task1: Lesson Plan
- Webinar: Topicals

Week3: Review

- Task 2: Applying group discussion
- Assignment1: Report on your practice

Week4: Problem Solving

- Slides: Problem Solving
- Task3: Lesson Plan
- Webinar: Sequences

Week5: Conversation

- Slides: Conversation
- Task4: Applying conversation
- Assignment2: Report on your practice

Week6: Conclusions

- Forum next steps
- Survey: Please share your outcomes

4 weeks course - Introduction

- Course Information and overview
- Survey: Please Share your interests
- Coffee break: Knowing each other
- Videoclip: ENGAGE Lesson
- Webinar: Engaging Science

Week1: Dilemma & Discussion

- Slides: Dilemma
- Slides: Group Discussion
- Forum: Topical Material
- Task 1: Lesson Plan

Week2: Reflecting on your practice

- Task 2: Applying group discussion
- Assignment1: Report on your practice
- Webinar: Topicals

Week3: Problem-Solving & Conversation

- Slides: Problem Solving
- Slides: Conversation
- Task 3: Lesson Plan

Week4: Reflecting on your practice

- Task 4: Applying conversation
- Assignment2: Report on your practice
- Webinar: Sequences

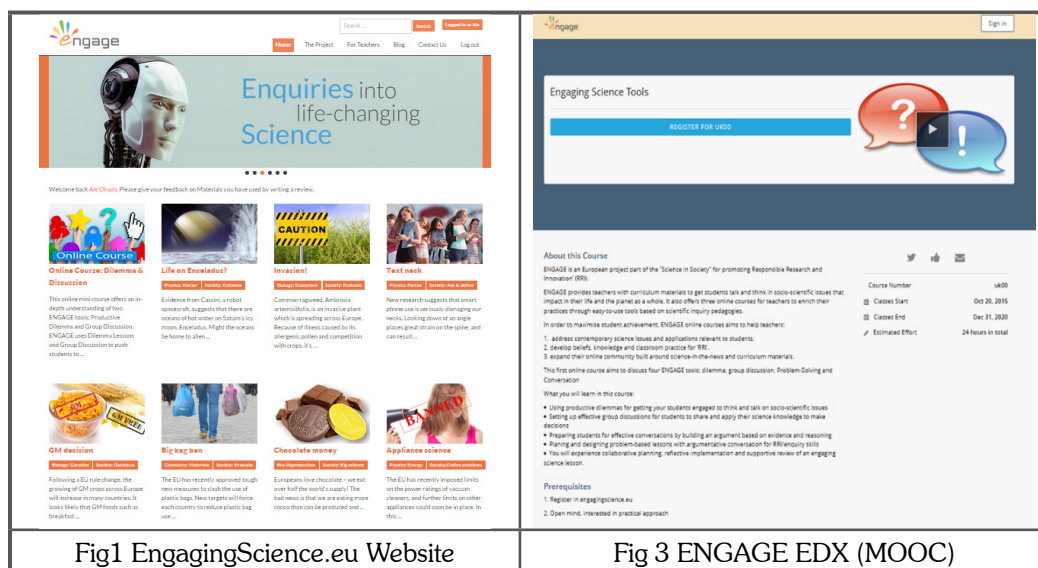
Conclusions

- Forum next steps
- Survey: Please share your outcomes

The ENGAGE project website provides you inquiry-based materials (OER) for developing pupils RRI skills and online courses (MOOC) for teacher's professional development.

Whenever you want to access the course, you must login using EngagingScience.eu website (fig1).

The first time you login to the course you will see the course webpage (fig 2) and you must also register in the edX platform (fig 3). If you are already registered and the course has started, the course (Fig 4) can be accessed directly from the ENGAGE homepage after you login.



The Top Menu shows four options: Courseware (Content), Course Info (Tutor's Messages), Discussion (All Forums) and Wiki (Your notes).

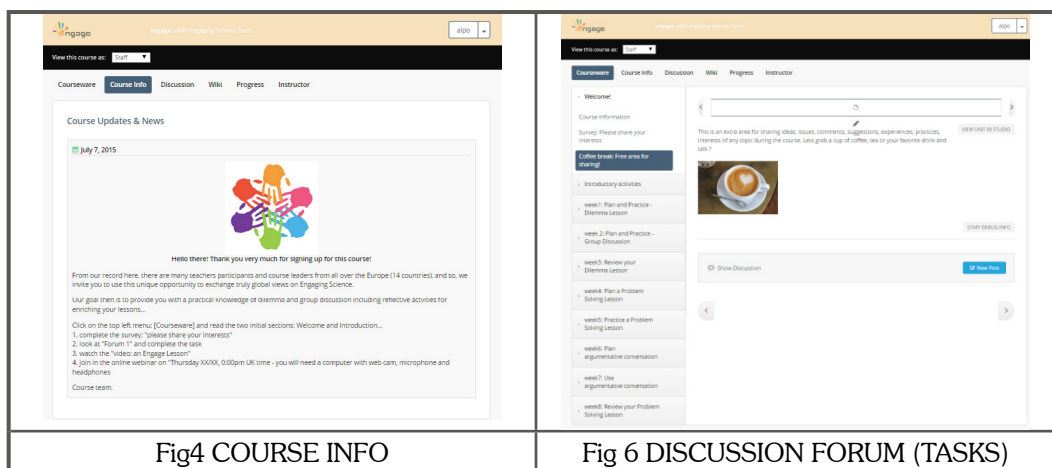


Fig4 COURSE INFO

Fig 6 DISCUSSION FORUM (TASKS)

You can set email notification of discussion posts by clicking on “[X] Follow this conversation”.

List of Materials (OPEN EDUCATIONAL RESOURCES)

The ENGAGE team developed a range of TOPICALS in different styles, which we then disseminated and tested out in the classroom. The content of the Materials is summarised in the table below.

LESSON AND OBJECTIVES	LEARNING OBJECTIVES
<u>TAKE THE TEST</u> Topic: Inheritance Skill: Devise questions Dilemma: Genetic tests can be used to determine whether a person is a carrier of a genetic condition – but is having a test always the best thing to do?	<ul style="list-style-type: none"> • Use knowledge about inheritance to interpret genetic diagrams, including family trees. • Make a decision by identifying issues that need to be considered in choosing to have a genetic test.
<u>ATTACK OF THE GIANT VIRUSES</u> Topic: Cells Skill: Interrogate sources Dilemma: Scientists have discovered a giant 30 000 year old virus still alive under the permafrost - could this wipe out the human race?	<ul style="list-style-type: none"> • How to interrogate sources to separate science fact from fiction. • Apply knowledge of microorganisms to check the facts in a newspaper report. • Evaluate how trustworthy scientific reports are in the media.
<u>MAKING DECISIONS</u> Topic: Inheritance Skill: Examine Consequences Dilemma: What could parents do if they want children and are carriers of beta thalassaemia major? Should they consider IVF and the genetic diagnosis?	<ul style="list-style-type: none"> • Explain how IVF with PGD can be used to help a couple with an inherited condition to have a healthy child. • Recognise ethical, social and economic arguments and use them to make an informed choice.
<u>INVASION!</u> Topic: Ecosystem Skill: Examine consequences Dilemma: Common ragweed is an invasive plant which is spreading across Europe. Should we control it by introducing non-native beetles?	<ul style="list-style-type: none"> • Ecosystem: How organisms affect each other. • Analyse and interpret: Evaluate a solution to a problem.

<p><u>GM DECISION</u></p> <p>Topic: Inheritance Skill: Estimate risks</p> <p>Dilemma Following a EU rule change, the growing of GM crops across Europe will increase in many countries, are they a risk to health?</p>	<ul style="list-style-type: none"> • Apply their knowledge about genes to learn why crops are genetically modified Genes: Describe what genetic modification is. • Science in society: Evaluate risks to health.
<p><u>EBOLA</u></p> <p>Topic: Inheritance Skill: Estimate risks</p> <p>Dilemma: would you trial a new Ebola vaccine? What are the risks and benefits?</p>	<ul style="list-style-type: none"> • Weigh up risks and benefits and make a decision, using scientific knowledge of the function of genes.
<p><u>BAN COLA?</u></p> <p>Topic: Digestion Skill: Critique claims</p> <p>Dilemma: Is there enough evidence for causal links between sugar consumption, obesity and disease? Should we ban sugary drink sales to under-18s?</p>	<ul style="list-style-type: none"> • Apply knowledge about food and health. • Use evidence to decide whether a correlation is causal.
<p><u>GROW YOUR OWN BODY</u></p> <p>Topic: Cells Skill: Critique claims</p> <p>Dilemma: Would you recommend to use new technology that allows to build new organs in a dish from cells taken from the patient's own body?</p>	<ul style="list-style-type: none"> • Apply knowledge about cells, tissues and organs in a new context. • Access, evaluate and synthesise relevant information to decide if a new technology will be possible in the next ten years.
<p><u>CHOCOLATE MONEY</u></p> <p>Topic: Ecosystem Skill: Communicate ideas</p> <p>Dilemma A chocolate company needs money to research decreasing yields: Can you work out a deal where all parties will benefit?</p>	<ul style="list-style-type: none"> • Ecosystem: why insect pollination is important in producing our food. • Science in society: understand who funds scientific research.
<p><u>THREE PARENTS</u></p> <p>Topic: Inheritance Skill: Use ethics</p> <p>Dilemma: Would you recommend a new procedure which creates babies with the DNA of 3 people in order to help women have a healthy baby?</p>	<ul style="list-style-type: none"> • Describe how to create an embryo with three parents, and explain this technique. • Use ethical arguments to make a decision about a new technology using ethical thinking.
<p><u>TEXT NECK</u></p> <p>Topic: Contact forces Skill: Devise questions</p> <p>Dilemma: New research suggests that smart phone use is seriously damaging our necks. Should use smart phone less to prevent neck damage?</p>	<ul style="list-style-type: none"> • Forces: identify forces on objects. • Ask and define: define a problem and devise a plan to investigate it.
<p><u>LIFE ON ENCELADUS?</u></p> <p>Topic: Particles Skill: Draw conclusions</p> <p>Dilemma: Evidence from Cassini, a robot spacecraft, suggests that there are oceans of hot water on Saturn's icy moon, Enceladus. Might the oceans be home to alien life?</p>	<ul style="list-style-type: none"> • Matter: how particle arrangements explain the properties of liquid water and ice. • Science in society: consider conclusions: assess the strength of evidence for a conclusion.
<p><u>SOLAR ROADWAYS</u></p> <p>Topic: Energy costs Skill: Critique claims</p> <p>Dilemma: Can we believe the claims about this new technology; are solar roadways worth funding?</p>	<ul style="list-style-type: none"> • Critique claims, using reasoning, evidence. • Apply science knowledge about generating electricity in solar cells, to make a decision.
<p><u>WHAT DOES THE FOX SAY</u></p> <p>Topic: Sound Skill: Critique claims</p> <p>Dilemma: Can we use science to interpret animal sounds?</p>	<ul style="list-style-type: none"> • Apply knowledge about sound waves. • Construct oral or written argument supported by empirical evidence and scientific reasoning.

<u>BAN THE BEDS ?</u> Topic: Wave energy Skill: Critique claims Dilemma: In preparation for a summer holiday many people turn to sunbeds to top up their tan but could this habit be endangering their life?	<ul style="list-style-type: none"> • Use knowledge about UV light to explain the link between sunbeds and skin cancer. • Understand how scientific evidence can support a claim.
<u>APPLIANCE SCIENCE</u> Topic: Energy costs Skill: Justify opinions Dilemma: Students have to decide how to cut their personal electricity consumption – do they go for a shorter shower or banish blow-dries?	<ul style="list-style-type: none"> • Solve a problem using scientific knowledge of the power ratings of electrical appliances and the energy they transfer.
<u>BIG BAG BAN</u> Topic: Materials Skill: Examine consequences Dilemma: Will degradable plastic bags solve the problems caused by ordinary plastic bags?	<ul style="list-style-type: none"> • Materials: properties of polymers. • Science in society: evaluate the merits of a solution to a real-world problem.
<u>CAR WARS</u> Topic: Climate Skill: Justify opinions Dilemma: Increased carbon dioxide emissions have led to huge financial incentives to buy alternatives to petrol engines – but which car is best?	<ul style="list-style-type: none"> • Apply knowledge about atmospheric carbon dioxide. • Evaluate solutions to the problem of increasing carbon dioxide emissions from cars.
<u>SINKING ISLAND</u> Topic: Climate Skill: Draw conclusions Dilemma: Students decide whether humans are to blame for climate change. Should the biggest polluters pay for land for vulnerable islanders to escape to?	<ul style="list-style-type: none"> • Apply knowledge about climate change to explain rising sea levels. • Make a prediction about rising sea levels and estimate the uncertainty in their prediction. • Evaluate evidence to decide whether humans are to blame for climate change.
<u>EAT INSECTS</u> Topic: Earth resources Skill: Communicate ideas Dilemma: Farming large animals uses precious resources. Can you persuade people to swap meat for insects?	<ul style="list-style-type: none"> • Communicate an opinion using evidence, persuasive writing and scientific knowledge of Earth's natural resources.
<u>DEATH TO DIESEL</u> Topic: Reactions Skill: Communicate Dilemma: Students use their knowledge of chemical reactions to predict the products of combustion in a diesel engine	<ul style="list-style-type: none"> • Predict the products of the combustion or thermal decomposition of a given reactant and show the reaction as a word equation.

DILEMMA LESSON	LEARNING OBJECTIVES
<u>ANIMAL TESTING</u> Science: Breathing Skill: Use ethics Dilemma: Will you sign the petition for a ban on all animal testing?	Breathing: show how asthma affects the structure of the gas exchange system Use ethics: learn 3 kinds of ethical thinking to make decisions: utilitarianism, rights and duties, virtues
<u>ELECTRONIC CIGARETTES</u> Science: Particles Skill: Estimate Risks Dilemma: Will you support a European ban on indoor vaping in public places?	Particles: draw before and after diagrams of particles to explain observations Judge risks: weigh up risks and benefits to make a decision
<u>TWO DEGREES</u> Science: Climate Skill: Examine consequences Dilemma: What will save the world from getting more than two degrees hotter?	Climate: describe how global warming can impact on climate and local weather patterns Examine consequences: consider the impacts of carbon emission actions on the environment, people and money

Gamification is the application of game-design elements and game principles in non-game contexts.

Topic	Steps	Players	Talk	Think
What does the fox say?	3	Group and individual	Discuss if people identify dog emotions	After listen to the sounds, discussion about spectrogram if people identify dog emotions?
GM decision	4	Group and individual	Discuss how to make a decision about genetically modified (GM) foods	Put the evidence list in importance frame and drag and build a framework
Eat insects	4	Pairs and individual	Discuss how Earth's resources are limited and need to be conserved	Create a menu for Christmas with insects and justify the choice
Sinking Island	3	Group	Discuss if humans can be blame for climate change.	Each student writes a testimonial in a card and share with the group to discuss
Car Wars	4	Group of 3	Discuss how to use what you know about atmospheric carbon dioxide in a new context	Game board and create framework by dragging cards
Invasion	4	Group and individual	Discuss how organisms affect each other	Write advantages and disadvantages to create a framework
Chocolate Money	2	Group (split in half)	Discuss why insect pollination is important in producing our food	Questions and answers to get higher amount of funding
Appliance Science	4	Several groups	Discuss the power ratings of electrical appliances and the energy they transfer	Drag the devices and to be calculated energy expenditure to be shown in a framework
Solar roadways	2	Pairs	Discuss about solar roadways	Drag the text in the right image and form the correct order
Text Neck	3	Groups	Discuss how to make a decision about whether to use your phone less to prevent neck damage	Drag cards with data collected in and set evaluative framework of contributions
Ebola	4	Pairs	Discuss the function of genes.	Read the sources cards and create a framework with the risks and benefits.
Making Decisions	6	Pairs and two groups	Discuss how IVF with PGD can be used to help a couple with an inherited condition to have a healthy child	Divide decisions cards, set up a framework with the results and put together a map of the decision
Take the test	6	Individuals and pairs	Discuss how to use knowledge about inheritance to interpret genetic diagrams, including family trees.	Answer questions and create a genetic diagram of your family. Discuss the risks.

Three Parents	2	group	Discuss about genes to explain how to create an embryo with three parents	Play a game of issues, count the number of issues that are for and against the technology.
Life on Enceladus	2	groups	Discuss whether the evidence supports the conclusion that there is hot liquid water on Enceladus	Organize evidence cards in a framework
Big bag ban	2	pairs	Discuss the replace ordinary polythene bags with degradable bags	Select the most important questions and interview experts
Ban Cola	2	group	Discuss if we should we ban sugary drink sales to under-18s?	Discuss using argument and evidence cards.
Attack of the giant viruses	3	group	Discuss the knowledge of microorganisms to check the facts in a newspaper report.	Read the newspaper report and use the information to fill in the table with the evidences
Grow your own body	5	Individual and group	Discuss which organs will we be able to grow in the next 10 years? Why? Discuss if should a friend get a lab-grown replacement trachea. Rank the argument cards and use them to write advice.	Complete the method and use the information to fill in the table and decide how long it will be before we have replacement organs. Rank the argument cards and use them to write advice
Death to diesel	5	Individual and group	Discuss the predict products of the combustion of a given reactant and show the reaction as a word equation	Complete the word equations, make a Checklist and create a vlog.
Ban the beds	3	Group and individual	Discuss about UV light to explain the link between sunbeds and skin cancer. Research of sunbeds causing skin cancer	Read the information, study the evidence and discuss what each shows. Record an interview for a TV show record video
Animal testing (1)	3	Pairs and groups	Discuss how important is animal testing for drug development?	Discuss the animal testing evidence cards and create framework.
Animal testing (2)	3	Pairs and groups	Learn 3 kinds of ethical thinking to make decisions: utilitarianism, rights and duties, virtues	Discuss the 3 kinds of ethical thinking and create framework.
Electronic cigarettes (1)	2	Individuals and pairs	Discuss if there is a scientific evidence that nicotine from vaping can get to people nearby	Draw before and after diagrams of particles to explain observations
Electronic cigarettes (2)	3	groups	Discuss if the benefits of banning indoor vaping in public places worth the risks	Weigh up risks and benefits to make a decision
Two Degrees (1)	3	Small groups	Discuss how the changes to weather and climate will affect people and wildlife	Drag and set a map with different temperatures
Two Degrees (2)	5	Group of 3	Discuss how the impacts of carbon emission actions on the environment, people and money	Create a framework with negative and positive consequences for actions

COURSE EVALUATION

The evaluation of MOOC's will be done with pre-enrolment and post-surveys.

The purpose of **pre-enrolment survey** is to inform the course tutors and the ENGAGE team about the participant's previous experience and interest in teaching about socio scientific issues. The information from the questionnaire will only be used anonymously in any research and is not an assessment of the skills of teachers.

The aim of **post-survey** is to gather data about the MOOC to improve future ENGAGE courses. It also gives data about the participation level of the participants, which activity is accepted as the most useful activity, to what extent teachers reach their aims and how the course influence them. The both surveys consist of tick box questions and there is also opportunity to include free text responses.

ENGAGE COURSE TEAM



ONLINE COURSE CORDINATOR AND EDITOR

Alexandra Okada is an honorary senior lecturer at the Open University in Brazil and Portugal and an interdisciplinary researcher at **The Open University, UK**. She holds M.A. in Computer Science, PhD in Education. She has managed various EU projects and is the principal investigator of ENGAGE - Legacy.

SCIENTIFIC LEADER

Tony Sherborne is the scientific coordinator of ENGAGE and the founder of science upd8. He is the Creative Director at **the Centre for Science Education, Sheffield Hallam University, UK** and an ex-NESTA Fellow.

REVIEWERS

John Wardle has a wide range of experience in science education, starting his career as a science teacher and progressing to his last post as head of **the Centre for Science Education at Sheffield Hallam University, UK**. He has developed a number of online programmes for science teachers and is now working as a consultant.

Kathy Kikis-Papadakis has extensive experience in RTD management with a focus on ICT and learning at various educational levels. Since 1993 leading the Educational Research and Evaluation Group at IACM/FORTH - **The Foundation for Research and Technology - Hellas, Greece**.

CPD FRAMEWORK

Yael Shwartz is a senior scientist at **Weizmann Institute, Israel**. She has been involved in IBSE curriculum development, implementation and assessment both in Israel and the US. She also has a rich experience in designing and implementing various models of teacher's CPD programs including on-line programs.

STUDENT'S MATERIALS

Gemma Young is a Science Publishing Editor, author and consultant. She has been developing learning activities for more than 7 years including those for Science UpD8 and Wikid sponsored by the ASE and the European Projects TEMI and ENGAGE. She is currently a research visitor at The Open University, UK.

Philippa Gardom Hulme is a science teacher educator, author and editor. She tutors on a postgraduate certificate of education (PGCE) course and has published around twenty science text books. She also writes online learning resources for students in the UK and abroad.

PEDAGOGICAL TOOLS COLLABORATORS`

Andy Bullough is the ENGAGE Project manager at **The Centre for Science Education - Sheffield Hallam University, UK** and curriculum developer

on the Astra Zeneca Science Teaching Trusts Science for All project. He has also a keen interest in science teaching and learning for pupils with special needs.

Maria Evagorou is an Assistant Professor of **Science Education at the University of Nicosia, Cyprus** and her research focuses on exploring and enhancing students' argumentation and system thinking skills within science education with the use of technology.

Sónia Hetzner: Senior researcher at **Innovation in Learning Institute - Friedrich-Alexander-Universität, Germany**. Responsible for development, management and evaluation of technology enhanced learning and training projects as well as information portals for different target groups.

Ignacio Monge contributes to continuing professional development of science teachers at **Haute Ecole pédagogique Fribourg/Pädagogische Hochschule Freiburg, Switzerland**. He holds Ph.D. in natural sciences and has ten years of experience in fundamental research and in secondary teaching.

Silvia Alcaraz is a researcher at the **Faculty of Education at Universitat de Barcelona, Spain** - "Virtual Teaching and Learning" group. She holds a M.Sc. in cognitive systems and interactive media, with a focus on ICT- based learning experiences for science teaching.

Foteini Chaimala is a researcher at **The Foundation for Research and Technology - Hellas, Greece**

She holds Ph.D. in the area of Peer Learning and argumentation by the aid of ICT. She has ten years of experience as a secondary and high school physics teacher.

VIDEO RESOURCES

Elin Aschim is an associate professor with Ph.D. in natural sciences at **Høgskolen i Vestfold - Vestfold University College, Norway**. She had nine years of experience in fundamental research and teaching before she started with science education for pre-service teachers and continuing professional development.

RRI EXTRA REFERENCES

Matteo Merzagora is a physicist and the scientific director of **Traces and director of the Espace des Sciences Pierre-Gilles de Gennes – ESPCI, France**. He teaches science communication and science in society in several French universities, and at the Master in Science Communication, SISSA (Trieste, Italy).

Vanessa Mignan is the **Traces'** public engagement hub manager, with degree in Chemistry and Physics. She develops, follows and assesses educational and training programmes both at the national and European level.

LOCALISATION

Dalius Dapkus is an associate professor at the Department of Biology and Natural Science Education, Vicedean of the **Faculty of Natural Sciences at Lithuanian University of Educational Sciences**. His interests include cross-curricular relationships and improvement of pre-service teachers' training.

TECHNICAL TEAM

Elisabetta Parodi is a Research & Development project manager at **Latanzio Group, Italy**. She has a degree in Informatics from University of Genoa, Italy. Since has been involved in European projects about e-learning practice and standards, knowledge management, mobile learning, virtual reality.

Mihai Bizoi is a computer scientist and lecturer at the Faculty of Electrical Engineering, Electronics and Information Technology, **Valahia University Targoviste, Romania**. He was/is involved in different ICT projects (research and educational) at national and international level.

EVALUATION

Dury Bayram-Jacobs is a post-doc researcher at Science Education and Communication Department at **the Delft University of Technology, Netherlands**. She has worked for 10 years as a Physics teacher. Her PhD thesis is about professional development of Physics teachers in different countries. She has managed several European funded projects.

“If you can turn science content into a tool for solving a problem or issue and hook students with the context, they will become more engaged with the concepts and more able to apply them later on. This is authentic inquiry.”

The ENGAGE project consortium

Sheffield
Hallam
University



Associated partners and collaborators

